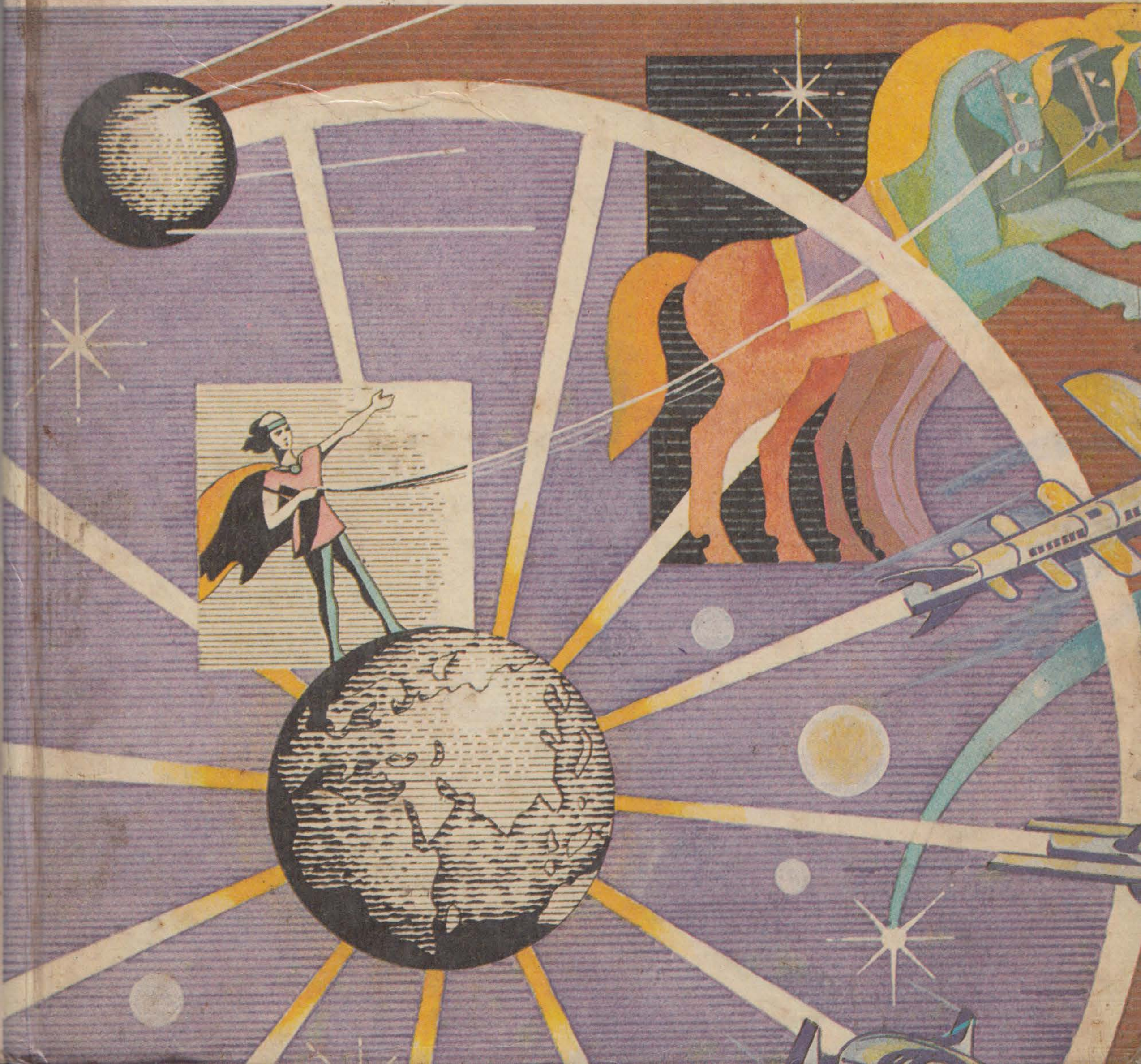
Anatoly Markusha

Miracles on Wheels



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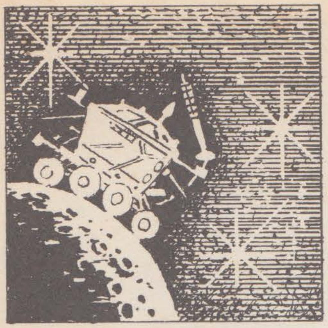

Anatoly
Markusha

Miracles on Wheels

(A Book for Inquiring Minds)

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Raduga Publishers
Moscow

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ЧУДЕСА НА КОЛЕСАХ

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About This Book and Its Author

This book has been written not only for budding engineers and mechanics: it is addressed to anyone who is thinking of becoming closely involved with machines and technology at any level, to anyone who is interested in the history of technology, or who likes to solve absorbing puzzles and make useful things with their own hands. In short, *Miracles on Wheels* is a book for inquiring minds.

The title of the book was chosen because our world literally runs on wheels, the wheels of cars, lorries and trains, and the wheels turning inside millions of machines. Wheels have a complex and dramatic history, a history which is also the history of technology.

Anatoly Markusha has written more than fifty books, and he never tires of telling young people about technology's past and present, about its development, its achievements and the prospects for its future. He always tries to help the young reader share his enthusiasm, and he explains how to master technology and find a common language with machines.

Before he began writing books, Anatoly Markusha had been a reporter for an evening newspaper, he was a fighter pilot during the war and he gained a qualification as a test-pilot. After his health forbade him to continue flying, he began working as a mechanic. It was then that he started his first book, entitled *You Have Take-off*.

He has now been writing books for over twenty years and his works have been published in over a dozen languages, both in the Soviet Union and abroad, with a total output of around ten million copies.

And always, in every book, the author returns to his main theme of Man and Machine. For him the world of technology is not merely a world of amazing machines, it is also a world of restless and thinking people who make great demands both on themselves and on others. The author calls on young people not to delay, not to put off their entry into this remarkable world. And his books help his young readers to make their choice and to find their way in an active and interesting life.

1

Three "Notches" for My Memory

The cool morning sun inundated into the room through the huge picture-window. The sun put a shine on the naturally bright walls of the spacious office, it was reflected from the glass doors of the bookcases, it broke against the chrome-plated stand of the model aeroplane on the desk and its rays were smashed into a wayward rainbow in the lenses of the Chief's glasses as they lay among his papers.

"Just the man," said the Chief as I walked into his shining office. "Come and have a look at this."

I approached his desk and took the large sheet of paper which he held out to me. In the upper left-hand corner was the legend "Top Secret", lower down the page and a little to the right was the word "Memorandum".

I looked at the Chief without trying to disguise my surprise. Both "Top Secret" and "Memorandum" had been scrawled in an uneven handwriting that looked like a child's. The letters seemed to be tottering and, in their agitation, elbowing each other out of the way.

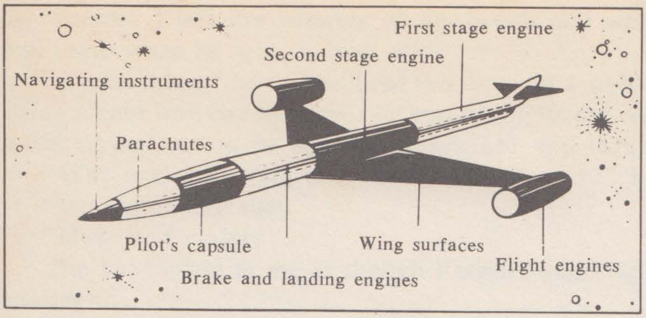
"Take a seat," said the Chief, "take your time, have a good read of it."

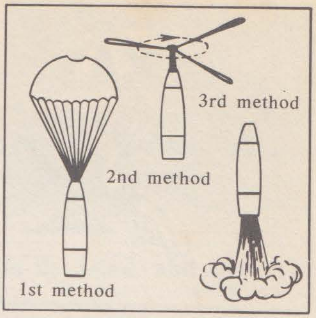
I sat down and began studying the document. The unknown author was suggesting a design for a flying machine of a quite revolutionary construction. The author's idea was that the machine would take off like an ordinary aeroplane and then, when it reached a height of around twenty or twenty-five kilometres, it would eject its wings and continue its ascent as a straightforward rocket. Thereafter, under the control of the pilot, it would either set itself in orbit round the Earth, or would become an interplanetary spacecraft.

The machine's return to earth would take place in stages: the ejected wings would make safe landings by means of parachutes, and then the craft itself would land by one of three possible methods. The first method would be by parachute, the second — by means of a rotor blade acting against the current of air through which the craft would be descending, and the third method — a vertical descent on a "gas jet" produced by brake motors.

"Well?" asked the Chief when I had put the "Memorandum" back on his desk. "What do you think of the idea?"

"Is that a serious question?"





"Of course it's a serious question."

"It's a mixture of simple technical ignorance and unbounded impudence."

"I'm sorry you look at it like that, very sorry. You should, I think, take note of the following points: one, the idea of freeing the craft from its wings, at a height where they can no longer be of use, is reasonable; two, giving the pilot control of the craft's flight path is also quite in order, and lastly, none of the three suggested means of returning to earth is in any way absurd. You're with me so far?"

"Well, yes of course, but..."

"Bear with me just a bit longer and listen to the crucial fourth point: the author of this document is twelve years old."

"Exactly! He's got to the grand old age of twelve, he's not really learnt anything in the world yet, he has no working knowledge of anything, and still he sets about building interplanetary spacecraft. That's just what I call unbounded impudence."

The Chief frowned. His kind and careworn face had become hard and distant.

"It's a pity," he said, "I didn't think for a moment you'd get so het up about it. I had wanted you to write a reply to this lad. Explain what's what. But I see I'll have to do it myself. Although I really haven't the time." And he made a gesture of despair.

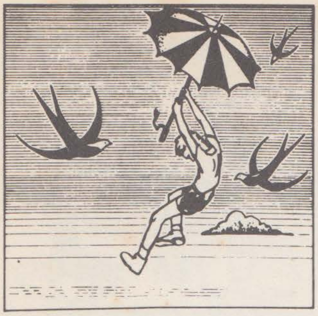
"Oh I'm not refusing to write the reply. By all means, I'll write it."

"No no, you couldn't do it, it's got you in too much of a temper."

And so the Chief didn't let me write a reply to the twelve-year-old boy. He wrote it himself, fourteen sides of it, typewritten! And that was the first "notch" for my memory.

It wasn't long after the above conversation that an old friend of mine came to call on me one evening. He was in fairly low spirits. We got talking, and he told me that he had had to operate — my friend was a surgeon — that day on a badly injured thirteen-year-old boy.

"Can you imagine it, he fancied himself as a rocket-builder! He'd put together some sort of three-phase technical wizardry, and filled it with offcuts of photographic film, gunpowder and matchheads. Add some other abomination, and it's all set for lift-off. And the whole caboodle exploded in his hands and cut him badly.



We had to amputate three fingers, and I feel sick when I think of the number of stitches he needed!"

The whole episode had made my friend very depressed.

"I'm sorry for the lad. But who's to blame? Can you tell me that, who is really to blame? How are we to protect idiots like him, in the space age? You can swear at them, whip them, even try roping them to a chair, but it won't do any good! The conclusion I come to is that we should teach them, explain things, make them more aware of technical ins and outs. Don't you agree?"

"Probably, yes," I said, and fell to thinking.

How come one inventor starts off with a "top secret" spacecraft, and another tries to blow himself up with a toy? There was definitely something wrong somewhere. The Earth is too small for the followers of Gagarin, they are afraid of missing out on the most interesting part and they really believe that fate is against them, that they were born too late, that time has passed them by. They are in a hurry. It's easy for us to rant and rave, and say "No, I forbid it". But the easiest course is not always necessarily the best.

When I was a boy, didn't I try to hurry the years along, didn't I envy my boyhood heroes like Valery Chkalov, our famous test-pilot of the 1930s, and the first man to fly between the Soviet Union and the United States of America over the North Pole? I don't make a secret of the fact that I tried jumping from the roof of our shed, using my granny's antiquated umbrella as a parachute; I was only a young lad, so I tried it. And I nearly broke my leg in the process!

That was the second "notch" for my memory.

One Sunday morning I was sitting in the small park near our block. There were children all around, playing and shouting. The younger ones were playing on the swings or coming down the slides with cries of excitement. The older boys were playing table-tennis. Two little girls were playing badminton. Then I noticed a young lad in the far corner, busily engaged with some rusty pieces of metal. The metal was old and, apparently, quite heavy. At first I thought it was just a heap of scrap-iron, but then I noticed him trying to undo some nuts, he was examining something closely and turning the whole thing over. That aroused

my interest. I left the comfort of my bench and went closer to ask this budding mechanic what he was so busy with.

"I'm learning," he said without too much of a welcome and not even looking up. Using a bent iron bar as a lever he was lifting up the remains of an engine (the rusty metal turned out to be an old car engine) and turning it over on its side.

"Why are you using that bar to turn it over?" I asked.

"It's easier like that."

"How is it easier?"

The lad looked at me as though I wasn't quite right in the head, and answered confidently:

"Because it's made of iron!"

It was my turn to wonder whether *he* was quite alright:

"What's made of iron?"

"The rod of course!"

"So what?"

"Well, it's easier with iron ... iron's heavy."

And that was the third "notch" for my memory.

An Unexpected, Though Quite Relevant, Digression

During the Second World War the following unusual, even fantastic, event was reported.

One day a Soviet "PE-2" dive-bomber was hit over enemy lines, and began to disintegrate in mid-air. The pilot ordered the crew to bail out, and then jumped himself.

The pilot landed safely among the Soviet artillery, but he was very worried about the fate of his navigator. While he himself was coming down, the pilot had not seen the man who was now missing. And, by rights, he should have seen him.

There was an hour and a half of tense and anxious waiting before the missing navigator appeared in the dugout. He was smiling and, judging by the expression on his face, he was quite unharmed. I will leave out the details of the reunion, as they are not pertinent to my main point. The pilot suddenly noticed that his mate had casually thrown his parachute onto the bench, but the parachute was still neatly packed.

I repeat: the parachute was still packed. The locks which operated the pack's release hooks were still fastened and the seals were unbroken! What could it mean? It meant, simply, that the navigator had jumped from a height of some 7,000 metres effectively without a parachute!

The explanation came later: he had left the 'plane when it was already breaking up, but he had hit his head on something and lost consciousness. Thus he fell the full 7,000 metres still unconscious. When he reached the ground his fairy godmother must have been watching over him; he landed by the edge of a deep gully which was so covered in snow that he landed like a torpedo into what was in effect a fluffy pillow of snow. As he fell through the snow his body cut a tunnel for itself some two hundred metres long, and he gradually slowed down until he came to a halt on the bank of a small stream covered with a transparent film of ice.

It seems to me that the above incident is a classic example of the concept of "chance".

And it was, indeed, a chance in a million that he survived, an improbable and exceptional stroke of fortune. And no one of course would dare assert, on the basis

of this one incident, true though it is, that escape from a disintegrating aeroplane is possible, per se, without a parachute.

I recalled this incident every time I thought of my three "notches".

Why?

Perhaps because I was trying hard to decide what was behind these "notches": were they just three chance occurrences (albeit exceptional and isolated incidents, but chance occurrences nonetheless), or were they elements of a single phenomenon?

To answer that question I needed, most of all, facts. Not three, not ten, nor yet a hundred, but many, many and many facts again. I started making inquiries, and I discovered the following facts: twelve- to fourteen-year-old builders of space rockets are rife here in the Soviet Union, you might say there's one on every street corner. The majority, it is true, confine their inventions to the pages of a sketch book (thank God), but there are some twelve-year-olds who take their sketches along to amateur engineering groups, to engineers of their parents' acquaintance, and with these self-same sketches lay siege to ministries, the Academy of Sciences and the editors of specialist technical journals.

Injuries arising from experiments with new technology are not yet innumerable but, unfortunately, they do occur. The boy who was treated by my friend is, alas, not the only casualty.

And finally, the lads using levers, and not understanding the basic principle of this most ancient of tools, turned out to be far more numerous than I had imagined. And these same lads, incidently, are not unaccustomed to getting good marks in physics.

I also found out, amongst other things, that there are considerably more youngsters trying to build fully automatic three-phase space wonders than there are, for example, those trying to perfect the ordinary bicycle (please note, I mention this particular machine deliberately), or trying to build a sand-yacht or a simple pump to provide water for the school garden. And what is more, even the most ingenious suggestions — and there are some, not many, it's true, but some do show signs of ingenuity — even these are often presented so untidily and incomprehensibly

that they have to be "solved", like riddles.

The conclusion is obvious: chance can be left to itself simply because it is chance, but a phenomenon may not be ignored.

I foresee the question: "And what, in your opinion, are lads supposed to do who are not old enough to start building rockets? And do you really think that invention is the prerogative of grown-ups? Really?"

To this I would answer: "To have a daring spirit is good, boldness of thought is fine, and vision too. But everything should be begun from the beginning, not from part way through, and even less so from the end."

And so I decided to write this book. A book for all future engineers and mechanics, for everyone who is thinking of spending a good part of their lives with machines, with technology, with the wonders which already exist and with those which will one day doubtless exist on our planet.

A Definition from an Old Dictionary

In a certain school in Moscow the children had been asked to write an essay with the title: "My view of an engineer's work".

In the event the vast majority of both boys and girls related the story of the science-fiction film "Engineer Garin and His Death Ray", and the few who did try to write something original tended to depict the work of an engineer as the continual study of something mysterious and bizarre, like the conquest of the forces of darkness or of things as yet defying accurate description.

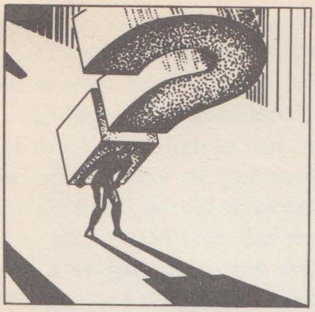
Children who know all the ins and outs of something as uncommon as the work of a test-pilot, children who can happily discuss the many facets of modern science, these very same children were unable to say anything meaningful about the work of a construction engineer and had only the vaguest of notions about the difference between the work of an architect and that of a building engineer. And what is worse, in not one of the hundred and eighteen essays was there a definition of the word "engineer".

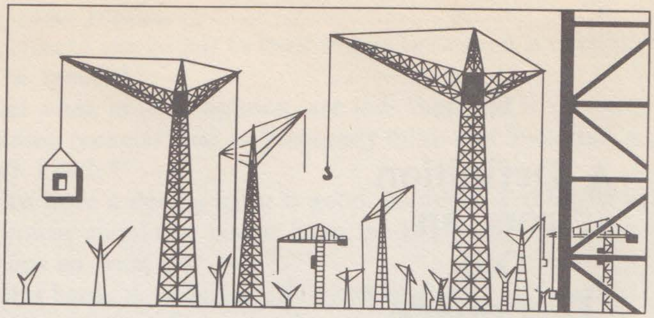
I must admit that I was very surprised and not a little dismayed. We would seem to come across engineers every day of our lives — and yet such ignorance! I decided to begin with a definition, as it were, a precise formula, so I opened the "Shorter Technological Dictionary". I was sure to find an exhaustive definition of the word "engineer". So, "engage", "engine", "engineering geology"... Alas, the word "engineer" had been omitted. The compilers of the dictionary seemed of the opinion that the word did not require definition, it's meaning was clear enough to everyone as it was. I turned to the "Encyclopaedic Dictionary": "engine", "engineering geology", "engine house", "englacial"... Again alas, the word had not been considered worthy of inclusion even here.

And it was only in an old book, published some sixty years ago, that I found what I was looking for:

"Engineer — a technical specialist concerned with the building of bridges, roads, fortifications, ships, machinery, etc. See 'Engineers'.

"Engineers — 1) military E.— officers of the engineering corps, responsible for the construction of all military installations; 2) mining E.— responsible for the working of mines and the winning of minerals; 3) transport E.— specialists in the building of roads, canals, bridges, etc.; 4) marine E.— in





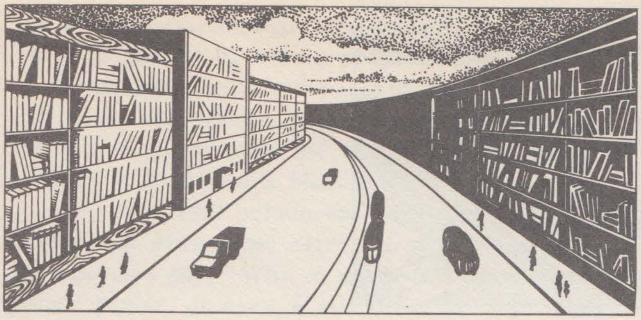
charge of the building of war-ships; 5) civil E.— architects, specialists in the erection of buildings; 6) engineering technicians — the title given to persons who have completed a course at a technological institute or have acquired similar experience therein; 7) mechanical E.— a) officers on war-ships superintending the machinery and workshops of the fleet; b) specialists in fitting out factories and mills with all the equipment necessary for their operation; 8) boundary E.— specialists in land measurement and the drawing of maps."

There is, of course, a great deal in this extensive description which is out of date and much again which falls short of the modern engineer's role. But the main idea holds true: engineering is one of the widest fields of human occupation. Engineers, we could say, are people on the ground and beneath it, people on the water and beneath it; they are people of the sky and of outer space. Engineers make life move wherever man needs the force of machines, tools and motors, wherever man needs precise calculations; engineers are to be found at the point where all the knowledge of physics, mathematics and chemistry — the whole range of the precise sciences — is required.

And engineers of course vary not only in terms of which branch of their profession they have chosen to follow, but also in terms of their individual characteristics. There are engineers who are genii, others are talented, others — gifted; there are yet others who are simply good engineers, there are ordinary engineers and there are, sorry though I am to have to admit it, even poor engineers. But all engineers take one and the same path: from the simple to the complex, from the ABC to the heights of their profession.

Sergei Pavlovich Korolyov, an outstanding Soviet scientist involved in the building of spacecraft, began by building gliders (in which, incidentally, he not infrequently flew himself); then he turned to the construction of aircraft and only after that did he begin to tread the thorny path of space engineering.

Andrei Nikolayevich Tupolev, one of the foremost Soviet aviation engineers, helped build gliders while he was still a student, he learnt to fly in them, then turned to building aero-sleighs. Then he began designing aircraft, light ones at first, then medium, heavy and finally some of the largest ever built. It took him most of his long and hard-working life to start building supersonic airliners.



Alexandre Gustave Eiffel achieved world-wide fame when he built the Eiffel Tower in Paris. But before coming to this now famous construction he had built a bridge in Bordeau, a viaduct in Garabit, a railway station in Budapest and many, many other engineering structures; all these earlier works were steps taking the man to the top of his chosen profession.

Nature did not stint on the talent which it gave to each of these men.

Which is why I would like to draw the attention of all future builders of interplanetary express ships to the great mass of work which still has to be done on our own planet. Think about things, experiment, devise new machines, better than those invented by your predecessors, but if you must specialise in the field of space technology then consider the more humble work that you do today as a training-ground for your work of tomorrow; remember that not even the most talented of long-distance runners began by running a marathon.

And if you are looking for a direction in which to channel your creative faculties, a subject on which to give your imagination free range, a task requiring bold technical endeavour, then just look around you and you will find a myriad of objects worthy of your attention.

Every day in school you see the blackboard, its paint wearing thin and scratched in a thousand places. This particular piece of equipment, as a teaching aid, was probably being used before the dark ages. So is the blackboard, with its powdery chalk leaving dusty marks on everything around — is this really a modern means of transmitting information? Can we not improve the technology of the blackboard? Increase its usable area, improve the legibility, give the blackboard a "memory"?

A nationwide competition is long overdue to find the best classroom blackboard — the blackboard of the twentieth century.

We live in a world of cosmic speeds and electronic machinery, but side by side with the most wonderful inventions of our age we still make use of things like spades and wheelbarrows. Much has been done of course in the last twenty or thirty years to improve the position, and a whole host of lifts, transporters, auxiliary machines and automatic loaders have been introduced: such machines are in operation at airports, on quaysides, in railway yards, on building sites, etc. But we are still far from the

perfect solution. Take a look, for instance, at the work of a shop assistant. Are many of his or her activities mechanised? If you ask the person behind the counter what the hardest part of the job involves, you will be told ninety nine times out of a hundred that it's fetching goods from the storeroom, especially in those cases where the storeroom is in the basement. So already we have an order that needs filling — devise a simple, compact and mobile automatic transporter-elevator!

Every day you see your mother doing her housework. And much has been done to lighten her load: multi-purpose food mixers, washing machines, vacuum cleaners and floor polishers. And yet mechanisation in the home is a long way behind the technical potential of our age.

The number of books on library shelves is growing day by day, growing at an incredible rate. Since the eleventh century, when the Chinese first started printing books, the world has seen the publication of over thirty million titles. The libraries of the world contain over eight hundred million volumes. And the rate of growth of the world's book "population" is not slowing down. Each year sees the publication of fifty thousand titles in the field of science and technology alone. Each year there are two hundred thousand new patents and essays printed. Each year there are over three million magazine articles. The list is practically endless. Ordinary books are incumbrances, and engineers have long since started taking copies of their bulky tomes, copies on microfilm; it is easier and more convenient to store microfilm or send it through the post, microfilms lend themselves well to cataloguing. This work of taking microfilm copies has begun, but it is far from complete, and it is perhaps one of the most urgent tasks which we face on Earth today: urgent, so as to escape the "flood" of books which threatens to drown us. Yet another order to fulfil — a fully equipped microfilm library.

Let us look at a totally different sphere of life. Despite all the advances made by chemistry and metallurgy we are surrounded on all sides by wood — from the cradle to the grave, as the saying goes. And whatever means we may use to cut and prepare the timber, be it with a powerful electric saw or a carpenter's humble hacksaw, those inexorable steel teeth leave us with a pile of sawdust. Fragrant and resi-

nous, this sawdust is thrown away, washed away, discarded, and mankind suffers a loss of incalculable magnitude. Forests grow only slowly, and the making good of the losses to date is becoming progressively more difficult with each passing decade.

If we could only find a way to cut timber without producing sawdust! Learn to cut planks like cheese, butter or salami, without waste! Whoever can devise such a method, whoever frees the world from sawdust will, I say it without exaggeration, provide a boon and a blessing to mankind.

Any observant person can continue the list of tasks to be undertaken. And my advice will always be: carry on, never stop looking for new tasks.

You may say: "Why so much talk about perfecting the school blackboard, or a potato peeler, or even a microfilm library? They're not that complicated!"

I don't agree. I don't agree at all! "Simple" and "complicated" are very much relative terms. To show you what I mean, I'd like you to picture one of the pages from the history of man's technical progress...

A Little Something from the Biography of a Most Useful Machine

If a young lad had said to his friend some fifty years ago: "What a great machine the Peugeot is!", his friend wouldn't ask him what he was talking about. Everyone knew that the Peugeot was a French bicycle. Nowadays the bicycle is rarely called a machine, it's more often referred to as a "bike", and shortening the word "bicycle" to the familiar "bike" hardly shows the right kind of respect for one of the most wonderful inventions of — comparatively — modern technology.

A "machine" in the minds of the lads today is a jet plane (preferably supersonic), or at least a motor car, or perhaps — with just a hint of irony — a motor bike. But a bicycle? No, I'm sorry, but what sort of a machine is that — two wheels held together by a piece of aluminium tube?

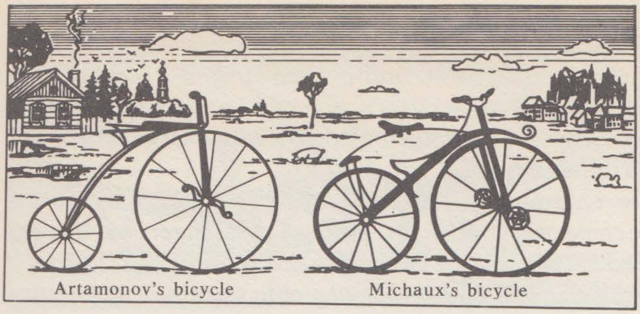
But young people shouldn't try to do the bicycle down. This apparently uncomplicated creation of human intellect, inspiration and inventiveness was and still is one of the most amazing achievements in engineering history.

Judge for yourselves:

The official date of birth of this two-wheeled self-propelling apparatus is normally put as 1813 and is generally ascribed to the work of Baron Johann Nikolaus von Dreyse. The story goes that Baron von Dreyse attached two cart wheels to a wooden frame, put a saddle on his strange steed and began riding around the country lanes and forest paths, using his feet against the ground to propel himself forward.

I should perhaps make one point here. Historians, studying the development of technology, know for certain that attempts to build a "self-running" carriage had been made many years before Baron von Dreyse's machine of 1813. For example, Yefim Mikheyevich Artamonov, a Russian self-taught inventor, had built a two-wheeler in 1801. The designers of these machines had a single, common obsession: to build a machine which would move of its own accord, without horses, without a motor, with no cumbersome, external source of power whatsoever. The common path of these persistent inventors had a success or two, but its disappointments were in the overwhelming majority. But the idea did not die out, it wandered from land to land, it lived with an obstinacy that defied reason.

Finally, as has already been mentioned, Baron von Dreyse hit upon the right design: two wheels and a frame. What could be simpler? Baron von Dreyse began riding



round on his two-wheeled cart, and hundreds of imitators began riding on similar contraptions. It was very soon discovered:

1) that the two-wheeled machine was best downhill. On a slope you could draw up your legs and give them a rest from the work of propelling the machine;

2) that it was possible, though not easy, to pick up speed along a flat road and to freewheel for some time thereafter;

3) that riding on this machine was tiring. It required very strong legs and stamina. And anyone of a weaker disposition would not withstand the jolting.

But Baron von Dreyse soon grew tired of his bicycle and he turned his attention to other things: he became interested in a railway wagon that could be set in motion by human muscle power. And indeed, it was this new sphere of activity which put the baron somewhat more firmly in the pages of technological history: one form of hand-driven railway trolley is named after him.

Other people were, however, on hand to take up the development of the bicycle.

In 1840, fully 27 years after Baron von Dreyse, pedals were attached to the front wheels of bicycles, rather much in the same manner as the pedals on a very small child's tricycle nowadays. This was a colossal step forward: the pedal bicycle gave movement to the machine without the rider's feet having to touch the floor. The machine's potential speed rose sharply, while the necessary exertion on the part of the rider decreased appreciably.

In 1845 a Frenchman by the name of Michaux (the man, incidentally, who gave the bicycle its more common international name "velosiped") fitted brakes to his machine.

In 1865, another 20 years on, solid rubber tyres were added. The hope was that these rubber "shoes" would make the machine travel more easily.

But it would seem that this hope was not fully realised as the Americans, going in for cycling in a big way, resolutely called the bicycle "the boneshaker", and never "the bicycle".

The next five years were spent on experiments to make the whole construction lighter. And it was at this stage that there was a minor "technical revolution": for

the first time the cumbersome cart wheels were replaced by light metal rims held together by very thin spokes.

Oh, this was a most important achievement, and it opened up all sorts of new possibilities: for instance, the diameter of the front wheel could be increased without difficulty. What for? I'll tell you why: for each turn of the pedals a large wheel will travel so much further than a small wheel.

And bicycles began to grow enormously, especially upwards. Travelling on the bigger machines, it is true, became more difficult, even more dangerous: but the extra speed was worth the risk!

The cyclists of those distant times still had one implacable enemy — the jolting and shaking. These huge machines (half as tall again as the average person) would squeak, creak and rattle along the roads making more noise than an ordinary ungreased and unsprung cart.

And then...

Before continuing the story of the bicycle it may be a good idea to make a small digression here into a completely different area of technology.

When the monument of the "Bronze Horseman" was being set up in St. Petersburg to the memory of Peter the Great, the founder of the city, the builders were faced with the task of moving the thousand-ton pedestal block, by hand, for a distance of six kilometres from the quayside to the place where the monument was to stand. The granite monolith was dragged along on cannon balls which ran along special wooden gutters lined with copper sheeting. This was the first use of ball-bearings in the history of technology. The principle was used the once, and then forgotten.

But now let us return to the bicycle.

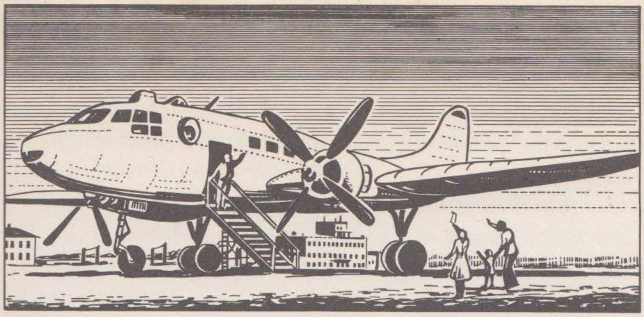
Tiny steel ball-bearings in the hubs of bicycle wheels produced the required miracle: the wheels now turned easily and noiselessly. That was in 1869.

In 1884 there was a further decisive leap in the biography of the bicycle: the invention of chain drive. This wonderful discovery removed the need for outsize front wheels. There was nothing now to stop bicycles being built smaller. A large cogwheel at the pedals and a small cogwheel on the rear wheel meant that a single turn of the feet would give several rotations of the driving wheel. The machine had become safe to ride.

Six years later, in 1890, an English vet by the name of John Boyd Dunlop put pneumatic tyres on his bicycle, and the offensive nickname of "boneshaker" was dropped like a hot brick. The two-wheeled machine now moved not only easily and quickly, but also smoothly. The bicycle had become an extremely swift machine, one of the swiftest machines of its time.

By the end of the nineteenth century the bicycle had begun to conquer the world. From being so recently an exotic toy, a plaything for the eccentric, it had become a mass means of individual transport, having the qualities of economy and convenience.

Suffice it to say that of the thirty thousand patents registered in 1896 in England alone, five thousand related in one way or another to the construction of the bicycle.



And finally, in 1897, the bicycle's driving wheel was given the ability of free-wheeling (whereas previously, since the introduction of chain drive, it had always been a fixed wheel).

Thus, ninety years ago the bicycle became, in principle, the machine as it exists today.

But that is not the finale, but only the beginning of this instructive biography.

It would be fair to say that no invention has made such a material impact on the world of technology as that of the humble bicycle.

Consider: the first aeroplanes with undercarriages took the design of their wheels from ... the bicycle. Automobile brakes and, much later, aeroplane brakes were developed on the model of bicycle brakes. The most reliable multiple-coil springs, used in machinery of all kinds, were first and foremost designed for ... bicycle saddles. And welded tubular bicycle frames were used as the prototype for welded aeroplane fuselages. What about the motor cycle? Isn't it just a direct descendent of the bicycle? And the scooter? And the moped?..

The bicycle turns out not to be such a simple machine after all. It is far from being a simple machine, it is a brilliant machine! Of the most modest construction, it is the most reliable of machines and the most meticulous in every detail.

I beg you, please don't call the bicycle a "bike". Treat this miracle on wheels with the respect it deserves, this miracle that is the result of the hard work, the impatience, the experiments, the enlightenments, the griefs and the successes of many thousands of nameless creative minds.

And I beg you, before you reject out of hand any idea on the basis of its apparent simplicity, remember the history of the bicycle. And think to yourself every time: is it really as simple as it seems at first glance, is it really such child's play?

For Those Who Are Not Convinced

In the previous chapter I tried to convince the inventors of new machines that one of the main qualities of an engineer, a builder, an inventor, or any person in the technological field, is the ability to see the seriousness of the work in the simplest of problems, to have the patience to perfect what has already been invented and to find the gradual approach to dealing with ever more difficult problems. I would hope that I succeeded in "converting" some of my readers to my way of thinking, but just as strongly I would expect someone to raise the objection: "In its time the bicycle probably was quite a thorny problem. But you haven't proved anything with your biography."

In anticipation of this objection I would like to ask the question: "Do you think it was difficult to invent spectacles, the ordinary glasses as worn by millions of people the world over?" To help you along I will tell you that lenses to regulate the sight already existed. The question therefore concerns the construction of the frames.

I am quite certain that the majority of my readers will answer: "What could be easier? Two wire circles, an arch-piece for the nose and a pair of ear-pieces. And there's your spectacles for you. Easy enough to make in a day."

But in fact it was nothing like as simple as that.

At first the glasses, by which I mean just the lenses, were fastened to the rim of the wearer's hat. Can you imagine the trouble it took to actually use this arrangement? If you want to read a letter or look at some very small object, up you get and fetch your hat!

Neither the long-sighted nor the short-sighted were satisfied with this solution to the problem.

So the lenses began to be sewn into a small belt, producing something akin to a mask for a fancy-dress ball. Would that do? Compared to the lenses being fastened to the rim of the wearer's hat, of course, it was an improvement, but it was far from satisfactory. Every time you wished to put your glasses on you had to tie the tape behind your head, and then to take them off you had to undo the knot.

And then at last there was a man with a bright idea: he thought of enclosing the lenses in a metal frame. He soldered a wire circle to either end of a small arched nose-piece. This was almost a pair of glasses as we know them today, except ... they

had to be balanced on the end of the nose, which was a feat requiring the dexterity of a circus acrobat.

And it was still some time yet before someone thought of fastening the glasses behind the ears.

That's how things happen. It was an apparently simple task, but mankind took three hundred years to solve it!

Don't get the idea that the mechanics, inventors, technicians and engineers of the past were hopeless imbeciles. Ancient engineering was an art which has left us outstanding examples of technical wit, brilliant discoveries and the highest flights of human thought.

The crux of the matter is in the very concepts "simple" and "complex".

What has already been discovered, the problems that have been solved and the things which have been constructed,— all this is *simple*. What has not yet been discovered, the problems that have not yet been solved, and the things which mankind has not yet succeeded in constructing in metal, wood or stone,— all this is *complex*.

Something to Think About, Problems to Solve

1) On the table is an ordinary oil lamp. You know what it looks like: the reservoir at the base, the wick leading from the reservoir, the small handle — usually in the form of a little wheel — to move the wick up and down so as to regulate the flame, the patterned metal rim around the flame and the bulbous glass tube resting inside the rim. Ah, hang on a minute!

Question: why the glass tube? And who introduced its use?

Don't be in too much of a hurry to answer, think about it carefully. If you were going to say something like: "The glass is there to stop the wind blowing the flame out! That's as easy as two and two makes four!", then your answer would be wrong.

2) Using the number 3 five times and setting them out how you like and combining them with addition signs, multiplication sign and what have you, can you make these five figures equal 31? OK, try it, it's not too difficult.

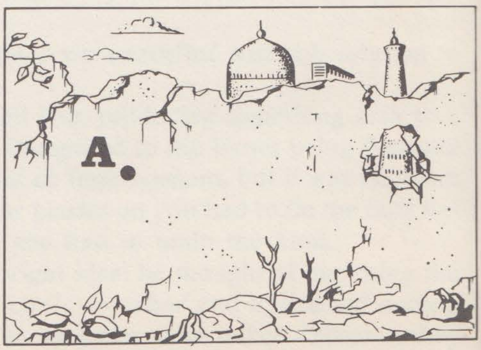
3) You will be quite familiar with the ordinary fork, you probably use one at every meal. But can you measure the volume of a particular fork, without using any intricate measuring instruments?

4) In the world of engineering it is often necessary to measure the area of an irregular surface.

As a rule the problem does not require perfect accuracy, so much as a quick solution.

To see how you would get on, try measuring the area of a leaf, say a maple or a sycamore leaf. If you don't have a real leaf to hand, you can cut out the approximate shape from a piece of paper.

5) On a wall somewhere there's a point marked *A*. Can you draw a straight line, through this point, perfectly hori-



zontally? One of your main difficulties, I should warn you, is that neither the ground at the base of the wall nor the top of the wall itself is level.

6) Can you heat up a nail or a piece of wire, without resorting to a flame of any kind, or to electricity, nor to something which is itself hot (such as hot water or a soldering iron)?

7) The table below shows five sums from which the plus and minus signs have been omitted. Can you enter the signs in such a way that each line equals 12? The quicker you can do it the better:

2 ? 6 ? 3 ? 4 ? 5 ? 8 = 12
9 ? 8 ? 1 ? 3 ? 5 ? 2 = 12
8 ? 6 ? 1 ? 7 ? 9 ? 5 = 12
3 ? 2 ? 1 ? 4 ? 5 ? 3 = 12
7 ? 9 ? 8 ? 4 ? 3 ? 5 = 12

8) You have a piece of plywood $8^1/_2$ centimetres long. You want to divide the length into thirteen equal parts so as to drill twelve holes at regular intervals for passing wires through. The question is, how to do this quickly, simply and sufficiently accurately?

9) In the following table please enter the missing numbers to make the sums correct both horizontally and vertically:

7	+	**?**	—	**?**	=	**5**
+		—		+		+
?	—	**2**	+	**?**	=	**?**
—		+		—		—
?	+	**?**	—	**6**	=	**6**
=		=		=		=
5	+	**5**	—	**?**	=	**7**

10) The following is the remains of a mathematical table. Can you look at it and, in less than three seconds, say what table it was when complete?

	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
2	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**		
3	**6**	**9**	**12**	**15**	**18**	**21**	**24**			
4	**8**	**12**	**16**	**20**	**24**	**28**				
5	**10**	**15**	**20**							
6	**12**	**18**	**24**	**30**	**36**					
7	**14**	**21**	**28**							
8	**16**	**24**								
9	**18**									
10	**20**									
11	**22**	**33**	**44**	**55**						
12	**24**	**36**	**48**							

11) Try drawing three straight lines on a piece of paper so as to pass through the four corners of a square, whilst fulfilling the following conditions: a) your pencil should not be lifted off the paper, and b) the end of the third line should come to the point on the piece of paper where the first line began.

Don't rush into it, think about it a little: the problem is not quite as simple as it may appear at first sight.

12) You are given eight balls, perhaps tennis balls or cricket balls, which are absolutely identical to look at. You are told, however, that one ball is a little lighter in weight than the remaining seven. How would you set about finding the odd one if you were allowed to carry out only three weighing operations?

13) Take a good look at the following table: you have one minute to study it:

4	**9**	**2**
3	**5**	**7**
8	**1**	**6**

Can you now say what is noticeable about this particular table?

14) What do you think: can an ordinary steel needle — like the one your mother or granny sews with — float on water?

15) If you are having a wash in a pond and you throw a mass of soap suds onto the surface of the water, you will notice that it breaks into individual soap bubbles which disperse over the surface of the water at once. Can you say why this happens?

When I was a boy, I always pictured Galileo Galilei as an old man with a long, shaggy beard, with the flashing eyes of a fanatic. This idea of him was presumably based on his well-known portrait.

And I still remember how surprised I was when I found out that his first scientific discovery — that time could be measured by a swinging pendulum — was when he was only nineteen years old; that this great Italian scholar was made professor of mathematics at the university of Pisa when he was only twenty-five.

Some Useful Hints

One day I asked a young lad I know:

"Vladimir, how do you count?"

He was quite nonplussed by my question:

"What do you mean, how do I count? Easy: one, two, three, four, five, and so on."

"Yes, OK. But what if your mother asks you to take some things to the laundry, and to count everything first so you know what you're taking? Then how would you count?"

And then I found out that my young friend would start by sorting out the washing, all sheets together, all towels together, and so on. And only then would he start counting: one, two, three, etc.

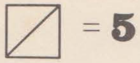
So I said to him:

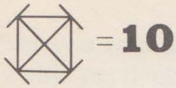
"You're not doing it right. The way you're going about it you're having to count it all twice."

"So?"

"But you don't have to. If you get a piece of paper, you can write down on it each of the items you want to count. Then, as each item comes to hand, you put a little mark next to the relevant heading. And that way you do it all in one go. It's a very useful way of counting when you have to both sort and count at the same time. Say, if you have to find out how many bolts, how many screws, how many nails of the various sizes there are in your workshop, or how many tins, and tins of what, there are in the store-room of a food shop, and so on."

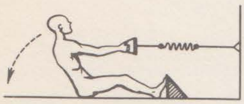
Incidentally, instead of a whole pile of simple marks next to each heading, it is easier to use some sort of cumulating system, arranging the marks into standard blocks of, say, five or ten. These standard blocks are also



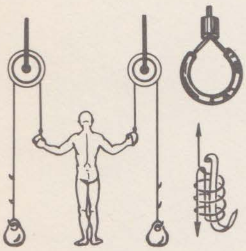


quite useful if you are ever having to keep score in volleyball, basketball, or other sport where the points mount up fairly quickly.

Another friend of mine, Sasha, once showed me his keep-fit equipment which he had constructed himself: it wasn't a particularly complex arrangement, but he had set it up in a most methodical manner. He had put a rope over a pulley suspended from the ceiling and had thus made himself an excellent piece of equipment for exercising his arm muscles. It's as simple as simple can be, and Sasha had put a good few refinements on it.



On the lower end of the rope, for example, he had attached hooks at different levels, hooks for attaching weights at different levels: a good idea, because it means he can change not only the weight itself but also the extent of the pull. He had fixed a hard plastic tube as the handle: again a good idea, because there's no point in asking for blisters on your hands. One other thing: all the fastenings on the rope were done very neatly, and not a knot in sight!



People concerned with technology, machines, engineering calculations, designing and drawing, all these people have to deal with figures. We learn to count as a process secondary only to learning to read, and everyone should be aware that 5, for instance, is greater than 2, and that 3 is less than 10.

But I would like to mention something else about counting. When you are dealing with real figures, real sizes and the like, rather than the theoretical numbers of an arithmetical exercise, you should make sure that you know what the figures represent, that you know their "value". For instance, if you are interested in the speed of something, then it is most important for you to know the "value" in which the speed is expressed: is it metres per second, kilometres per hour, or perhaps miles per hour? You must not try to add 3.5 m/sec. to 6 km/h. First of all you have to put both speeds into a common unit of measurement, either m/sec. or km/h. Moreover, it is totally impossible to compare measurements expressed in different units: 300 m/sec. and 500 km/h., which is greater? It is not easy to answer straightaway.

This is nothing new, of course. But I just want to stress to all budding engineers the importance of the value behind a number. Be sure you know what the value is, and don't forget to write it down. If you don't write it down, how are you going to answer the question: "You have written here: diameter of circle—5. Is that big, or small?" Of course, a diameter of 5 millimetres is about the head of an average nail, but 5 centimetres is a fair-sized water-pipe.

And do I need to point out that an engineer, or anyone in the world of technology, if he wants to keep up with the times, should be prepared to read, to read a lot and to read regularly, he should be prepared to make books an integral part of his work.

I would strongly advise to make a good note of the books you read, and the note might be in the following format: author, title, publisher, date of publication. Just a couple of lines for each book and you will be able, at a moment's notice, to find the particular book you are looking for; what's more, you should never have to start racking your brains: "Oh heck, what *was* the man's name — Kolin, Kozin or was it Kovin? It was something beginning with 'K'. It was a good book, that one. What was it now: *Fire on the Mountains* or was it *Mountains in the Fire*?"

I would also advise you to make a note, a very short note will do, of what each book is about. One book might give the following note:

"Artobolevsky I., Kobrinsky A. *May I Introduce You to the Robots*, Molodaya Gvardia Publishers, 1977. The book is about a new class of machines — robots capable of imitating human limb movements. Academician Artobolevsky, founder of a school of mechanical theory. Kobrinsky, professor of cybernetics, author of popular-science books."

A short note like this will allow you to recall what you may have forgotten and will help you find whatever material you are looking for, whether it be for a lecture or simply to be able to point a friend in the right direction.

But that is not all. When you are reading a book, especially a technical book, make a note of the more interesting facts, examples, or any relevant numerical data.

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And don't forget to write down where this information has come from. Let's say you are interested in a few hints about how best to construct the ribbing for a model 'plane, and you find these hints in an issue of *Modellers' Weekly*. Great! Make a note of how to cut the bamboo or balsa correctly, how to make the splints into the proper curved shape, how to apply the cotton binding — basically you should write down anything which you think it may be useful to know. And don't forget to note: magazine such-and-such, issue such-and-such, page such-and-such. And then you won't have to start wondering where on earth you got all these hints from.

Working with books like this can seem pretty boring at first, but when you get into the hang of things, get used to making these notes and build up your own little store of technical information, it will become far more interesting and you will realise just how useful and necessary this approach is.

When you are taking apart a mechanism of any sort, even the most straightforward, and especially if you don't have an assembly plan or diagram, you should never strew all the bits and pieces over your work-bench, particularly the smaller items such as washers and little screws. Try to set them out in the order in which you take them off the mechanism, and make sure that each bolt is put together with its own nut, and that each washer is put together with the nut to which it belongs. If, along the way, you have to disconnect electric terminals, be sure to mark the loose ends (paint, chalk, anything will do, or a label attached to each wire in some way).

And don't begrudge the time you spend on this, even though it may seem to you to be an unnecessary chore. When you get around to the re-assembly you will soon make up all the minutes "lost" while you were dismantling the mechanism.

If ever you come to take apart something that's caked with filth and grime, the hub of a bicycle wheel for instance, you must always clean each piece as you take it off and then wipe it dry. Why, do you think, is it so important to do this at the dismantling stage? Firstly, to avoid getting unnecessary dirt and filth on your work surface; and secondly, so that when you come to re-assemble, you have all clean parts to work with.

When you are using very small machine parts it is always very useful to have a safe place to put them: a metal trough divided into a number of compartments, or a number of lids off jars, or perhaps a collection of small plastic saucers — anything in fact that will stop tiny screws or washers and things from rolling around and getting lost.

Tidiness is a virtue in whatever you do, but when it comes to dismantling and re-assembly it is an absolute must.

As a boy Isaac Newton once built a model of a windmill, the sails of which would turn even when there was no wind. His elders looked on him and his toy somewhat warily: was it possible that the young lad had dealings with the forces of evil?

But the secret of the windmill was quite simple: inside the main body of his construction Newton had fixed a wheel, the sort to be found in the small cages for mice, and there was a mouse in this wheel too.

At the age of fourteen Newton built a water-clock which told the time as accurately as any other clock invented to date.

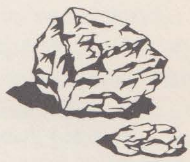
These were still early days for the man about whom it was later said:
"Nature, and Nature's laws lay hid in night:
God said, Let Newton be! and all was light."

Dates on the Calendar

"Dates on the calendar", of course, cannot by any means reflect fully all the various events connected with the development of technology. And if only for the reason that a single page, dedicated to each year of human activity to date, would add up to over one thousand five hundred encyclopaedic volumes. Also, different epochs have left us with different heritages, some quite extensive, others rather less noteworthy.

The only intention behind my "dates" is to give an indication of the stages along the road which man has travelled in the world of technology. I am hopeful that this extremely sketchy "potted history" will be of some use: it may raise in your heart a feeling of respect and the deepest gratitude towards those restless spirits who began by picking up a stone from the thorny path of progress and have got as far as putting a man into outer space; these restless spirits have not grown tired, and they continue to stride forward, ever further, ever higher.

800,000-400,000 years BC



This is the Eolithic Age, the time of the earliest stone implements of a very primitive type, made by sharpening natural flints.

400,000-100,000 years BC

Men begin to use rough stone hand-axes. These continue to be made by sharpening natural stone; they are around 18-20 centimetres long and weigh anything from 50 grammes to two kilogrammes. Man gradually begins to attach a handle to the stones.

At this time, also, our ancestors get to know "natural" fire.

100,000-40,000 years BC

Very sharp stone instruments, including chisels, and instruments made from bone, come into fashion. Man's workshop not only acquires newer tools, but also, and more importantly, man himself prepares instruments of different constructions for different purposes.

Man "tames" fire, and begins to live in caves.

40,000-12,000 years BC

Bone instruments, stone chisels and other scraping tools are used more and more frequently. The stone is sharpened by chipping away at it; by this means the stone can be shaped to a particular requirement, and points and edges can be made extremely sharp.

Man begins to live in holes dug in the ground.

Pavel Nikolayevich Yablochkov, was the inventor of the "Yablochkov candle" and other electrical lighting instruments which first began to shine in Paris. In this capacity — as a talented electrical engineer and a tireless researcher and inventor — he is known throughout the world. Perhaps less well known is that as a twelve-year-old boy he invented a measuring device which the peasants of the Serdobsk district, where Yablochkov then lived, continued to use for many years.

René-Antoine Ferchault de Réaumur invented the spirit thermometer which now bears his name. On Réaumur's scale snow melts at 0°, and water boils at 80°.

Réaumur carried out studies in physics, chemical technology, zoology, botany and other sciences. His Mémoires pour servir à histoire des insectes *is a work filling six whole volumes.*

Réaumur was elected a member of the Paris Academy in 1708, when he was only twenty-five *years old.*

The year is 1910. The place is Kiev. The well-known aviator of the time, Sergei Utochkin, has nearly killed himself: his magneto failed on take-off, the engine cut out, and the aeroplane crashed to the ground.

The following day a fifteen-year-old boy came to Utochkin and suggested:

"You should have two magnetos, in parallel; if one fails, the other will keep you going. I was at the aerodrome yesterday, and later I saw a one-eyed man in the street. That gave me the idea..."

The lad was nervous and his speech was muddled. But his idea was brilliant, and Utochkin used it.

In 1936 the world heard the name of Valeri Chkalov: he made his historic non-stop flight from Moscow to the Soviet Far East in a single-engine aeroplane. Everyone remembers the 'plane — an ANT-25, but what about the engine? It was an AM-34, built by Utochkin's young admirer to become a leading Soviet aviation designer and a member of the Soviet Academy of Sciences, Alexander Alexandrovich Mikulin.

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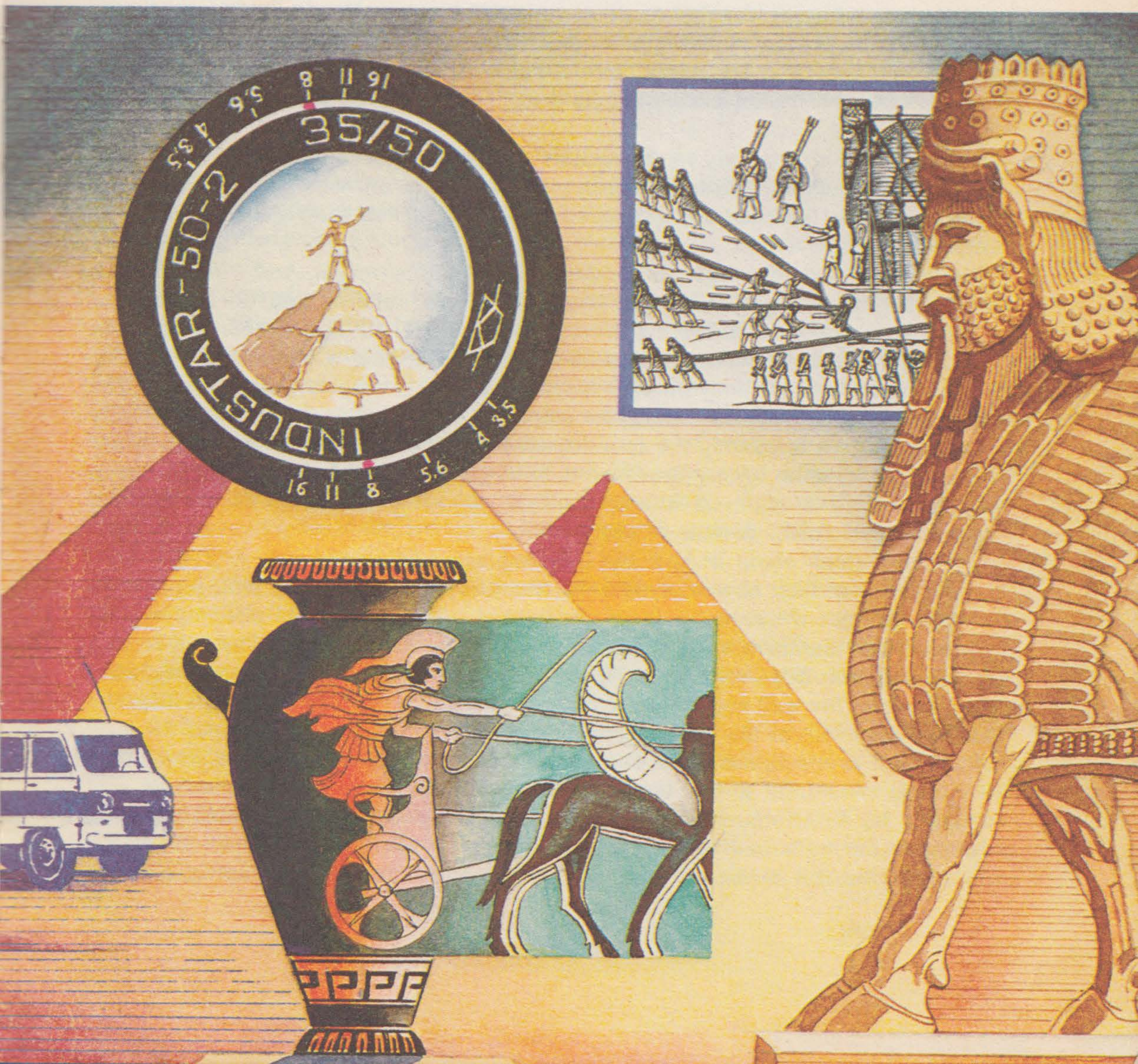


Something Quite Clear, and Something Not So Clear

Anyone who has decided to devote himself to technology will of course understand that you can't build a jet engine, for example, without a good knowledge of mathematics. Or a budding electrical engineer will hardly get further than the most primitive of radio receivers if he doesn't have a good knowledge of physics. Fine.

But what I want to say to the soldiers and generals of our future technological progress is something a little different, something — in my view — most important. Take a look at the road leading back into the past, both the recent past and the darkest past.

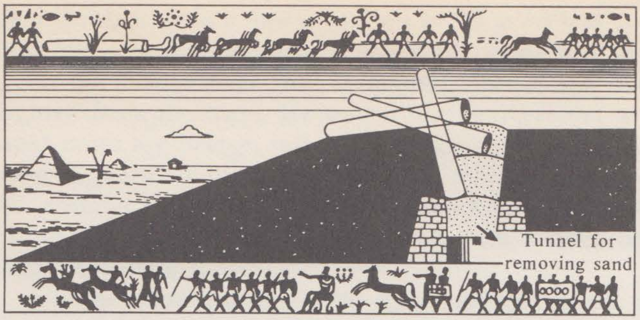
Five thousand years ago our forefathers built the pyramids. And what pyramids they are! The pyramid of Cheops was built of two hundred and thirty thousand stone blocks, each weighing on average two and a half metric tonnes. But the builders of these magnificent structures didn't know what a wheel was!

Around the same time we find the most amazing temples being erected. The engineers of those distant times, who were not yet called engineers, were able to set up a column in exactly the spot intended for it; and each column was a single piece of stone, up to twenty-four metres in length and anything up to 400 tonnes in weight! This was achieved without pulleys, without a block and tackle, without complex mechanical devices of any kind.

Have a think about it: how did they manage it?

I'll tell you. First of all they laid the foundation, and then they built stone walls around the spot where the column was to stand. Earth was then piled up around these walls so that there was a gentle slope leading up from all sides. The well formed by the walls was filled with dry sand, and all was ready. The column was dragged to the mouth of the well and its lower end was placed on the sand. Through a special tunnel at the base of the well the engineer would remove the sand and, as the level of the sand dropped, the lower end of the column would drop with it, the column would tip over until it was upright and would finally come to rest on the spot designed for it. All that remained to be done was to remove all the piled-up earth, dismantle the walls and the task was complete.

I mention this means of raising a heavy column for a good reason; and not



because I think the idea might come in useful nowadays! We live in an age of highly mechanised construction processes: a crane would do a job like that a hundred times more easily and, no doubt, a thousand times more quickly. Nonetheless, the experience of these ancient engineers may be able to teach our future engineers a thing or two.

Such as?

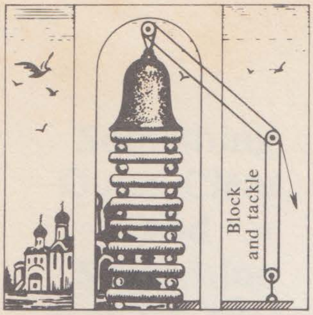
This experience tells us not to be put off by apparently unresolvable problems, and to look for the simplest of solutions in the most complex of situations. That is why a knowledge of history, even of the darkest past, can be quite useful, even for the future.

Every person with an education will know the life-story of Leonardo da Vinci, so I would like to mention just a few of the more relevant facts from this life-story: as a boy Leonardo was taught reading, writing and arithmetic; at the age of fourteen he was apprenticed to the artist Andrea del Verrocchio, and spent his time grinding dyes, drawing figures for his teacher's paintings, moulding statues, and he even turned his hand to construction and the art of smelting; at the end of his apprenticeship he entered the service of the governor of Milan, Ludovico Sforza, where his duties were — in modern terminology — those of artist, engineer and bombardier; he made statues, painted pictures, constructed buildings, drained marshes and built machines.

Of course, there's no way you can become a genius "to order". But I do recommend that you learn from Leonardo da Vinci: always try to extend your range of interests, develop an avid interest in everything unknown to you and learn to take things one at a time, starting with the basics and moving on to more complex matters.

And another piece of advice: follow the example of the Renaissance's first engineer and do not disdain any type of work, try your hand at every trade.

The engineer of the twentieth century doesn't have to be the best metal worker in the factory, workshop or laboratory, but his work will be impossible if he knows nothing at all about the metal worker's craft. His work will be impossible if only because he will be in charge of metal workers, welders, turners and the like,



and being in charge of means not only knowing their work but also being able to do it himself.

If you look through the pages of the Russian chronicles of the seventeenth century you will find that in the year 1668 a huge bell was raised to the Kremlin belfry. The bell weighed 8,000 puds (that is over 128 tons) and took nine months to put in place!

A person who, by nature, does not have an inquiring mind will have read the last paragraph and have said: "Interesting, yes, very..." And he will have turned the page. But what of an inquiring mind?

First of all, the inquiring mind will stop and think.

The inquiring mind will want to know how his bold forebears managed to lift an almost 130-ton monster up a bell-tower. And he won't be satisfied until he learns that the bell was raised step by step: a block and tackle was used to lift it a little and at the same time logs were placed under it to hold it there; first there was one layer of logs, then two, then three... And so it reached the top of the belfry. The inquiring mind will appreciate the brilliance of the solution to the problem, its innovative nature and its apparent simplicity. The inquiring mind will not repeat the philistine axiom of: "Live and learn — and you'll still die a fool", he will say to himself: "You learn something new every day!"

In 1851 a railway line was opened between Moscow and St. Petersburg. In those days it was considered a marvellous and modern construction and it goes without saying that there was widespread interest in Russia's first steel highroad. At the time transport was almost exclusively by cart or carriage, horse-drawn of course, a system of transport that required, in Russia, some 800,000 people to keep it going in summer and up to three million in winter!

Tsar Nicholas the First thanked the engineers for their efforts and handed out favours right, left and centre, and said he wanted to ride on the railway, and ride he did.

The Tsar's train would stop before each bridge, the Tsar would alight from his luxury carriage and ... he walked across the bridge after the train. It wasn't that he had a particular interest in the construction of the bridges, he was simply afraid of

them. Bridges were a new invention as far as he was concerned, what if they should suddenly collapse? And the Lord helps those who help themselves, as they say.

At the bridge over the Verebinski Ravine the Tsar made his usual stop and alighted from the train. He waved his handkerchief as a sign to the driver that he could cross the bridge, but... The train stirred, its wheels turned, but it would not move forward. It turned out that the man in charge of this particular stretch of rail, wishing to impress His Majesty and knowing that His Majesty would "inspect" the bridge, had painted the rusty rails with a thick oil paint. And well, the paint hadn't had time to dry.

I have recounted this little story not just as an amusing anecdote from the history of technology, but because I want the reader to consider the passage of time: less than a hundred and fifty years ago the Tsar — the head of the Russian Empire — was afraid to cross a railway bridge! And a railway officer, a technically qualified man by the standards of his own time, took less interest in the laws of physics than in the ways of candid servility. How the leading figures of Russia really stand out against this background, the builders, the mechanics and the engineers!

I strongly recommend all those entering on the path of engineering to take an excursion into the past. Get to know your predecessors of all ages, and learn from their experiences. These experiences are interesting not so much for the knowledge which they led to, as for the human traits which they show us. They don't show us so much how to build, how to solve problems and how to overcome technical difficulties, as much as how to live honestly and with integrity.

As Maxim Gorky, the founder of Soviet literature, once wrote: "Schools should introduce one more, very important, subject — *the History of Labour*, the brilliant and tragic history of man's struggle with the natural world, the history of his discoveries and inventions, his victories and triumphs over the forces of nature."

And a little later he wrote: "I believe very strongly in miracles made by the intelligence and imagination of man; I know no other miracles."

The Indispensable Language

The brightest minds of our age are racking themselves silly over the problems of machine translation.

As though it were the simplest thing in the world, the multitude of science-fiction writers tell us about people of all lands and nations, as representatives of our civilisation, communicating with the ambassadors of other planets, communicating freely with the help of computers.

So what's it all about? Why has this question — the question of uninhibited communication — become such a universal theme?

It's quite simple really: it is absolutely indispensable for man to overcome the barriers of language. And the sooner these barriers are overcome, the better. Children nowadays are far more inclined to learn foreign languages than we, their parents, were. And everyone knows that you cannot become a specialist in any field without having read the relevant books in English, French, German, Japanese or whatever.

But there is a problem still: many youngsters turn away from other paths than the learning of foreign languages, although these paths have existed for a long time and have served mankind well for many, many years.

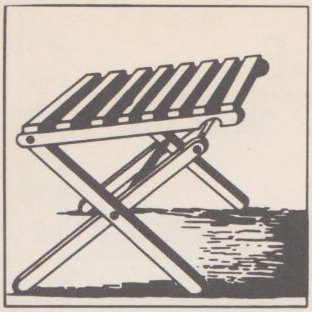
I have a friend, Sasha, an intelligent fourteen-year-old, an inventor, a master craftsman with skilful hands, and — in his own imagination at least — a budding chief construction engineer. But he never tires of telling me:

"Maths is OK, physics is OK, but I can't stand drawing lessons!"

And I can never get it over to this future chief engineer that a clear, explanatory drawing, graph or diagram is as yet the most international and the most reliable means of communicating technical information.

Just imagine: a gathering, let's say, of electrical engineers, an Englishman, a Swede, a Pole and a Russian. The Swede doesn't speak Russian, the Englishman doesn't know a word of Polish, but they can still understand each other's ideas, appreciate each other's achievements and find each other's errors: and only because their ideas are set out in the clear, concise symbols of drawings, graphs and diagrams.

Every person who has dealings with technical information must be able to



What experiments an engineer has to make just to find out the truth!

How were the specialists to answer their air-freight problem: do suitcases burn well?

To answer this question they set up an experiment and found the following: luggage smouldered during flight for twenty-four hours before the walls of the luggage compartment burnt through. The specialists were therefore confident in confirming: suitcases burn slowly!

read the language of drawings, must be able to express himself in this language, must be able to set out his arguments.

Now, please, have a little patience and read the following short description:

The upper cover is rectangular in form, its surface consisting of eight laths each measuring 300 mm. by 20 mm. by 8 mm. The laths are placed 10 mm. apart and are fixed to two transverse supports each measuring 300 mm. by 30 mm. by 25 mm. The ends of these supports are slightly rounded, the radius of the rounding being 20 mm. At one end of each support a hole has been drilled with a diameter of 15 mm., whilst at the other end a notch has been carved...

"Stop it! You're boring me to death!" I hear even the most patient of you cry, even before you've got past the first five lines.

And, incidentally, this is the beginning — yes, only the beginning — of the description of an ordinary folding stool, just like in the drawing.

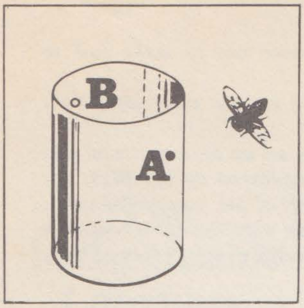
Our language is far from adequate, it is feeble when it comes to technical constructions (it doesn't matter whether the constructions themselves are simple or complicated); a drawing, on the other hand, is eloquent, persuasive and, most importantly, it presents an image of the matter in hand. The object — take the above-mentioned stool for example — is not in front of you, but you can see it, see it in all its details. Moreover, with the help of standard cross-sections you can look into the heart of the object as though with an X-ray machine, you can see internal ducts hidden from the naked eye, you can see cavities, drill-holes, threads, hollows...

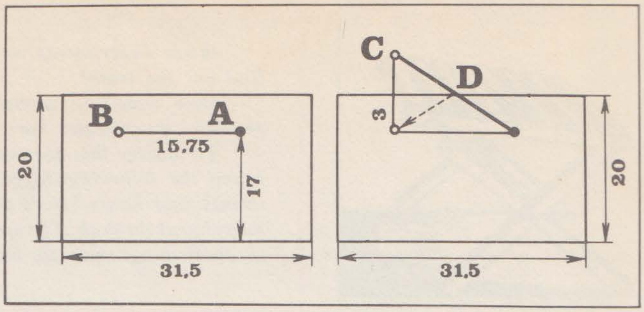
A drawing gives the most graphic of presentations.

When you begin your journey into engineering, do get used to the language of lines, the standard symbols and notations, understand the expressiveness and tangible quality of cross-sections. Even if you intend to be only the most humble of engineers you still need to know how to read, understand and "feel" drawings and diagrams. Without such knowledge you won't be a qualified lathe-operator, let alone an engineer.

So why *does* my friend Sasha insist on saying: "I can't stand drawing lessons!"?

I think probably because Sasha has not yet learnt to see the wood for the trees. As far as he is concerned three projections of a truncated pyramid only mean a mark





in his school report, say six or seven out of ten, nothing else. And I must say, I can understand the lad. Sitting through drawing classes merely to learn how to join lines together, how to find a point of intersection or how to draw cross-sections neatly, that's hardly likely to be everybody's cup of tea. Just as there's unlikely to be many people who so dearly like to learn the rules of the present, perfect, future and past-historic merely for the sake of the rules themselves! It's quite another matter to absorb the grammar of the German language so as to be able to read Heine fluently in the original, to get more than a passing acquaintance with the works of Schiller, to have a conversation with a real, live German...

It is not, incidentally, that difficult to feel the "need" for drawing. If a person invents something quite simple, say a bird-box unlike any that's been made before, and if he can set his idea down on a piece of paper, then he will be able to put his bird-box together, without a hitch, just as he designed it and every nail will find its rightful place, and he will immediately agree: yes, the ability to draw is indeed a most useful accomplishment!

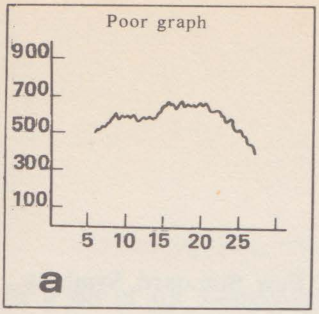
Drawing helps not only to see things better, but also to solve many problems more easily. There's one classic riddle, "the path of the fly", it goes as follows:

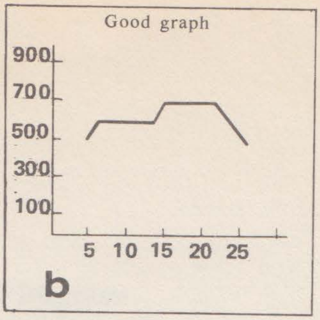
"There is a drop of honey on the inside of a cylindrical glass jar; it is three centimetres from the upper rim of the jar. On the outside of the jar, at a point diametrically opposite the honey, is a fly.

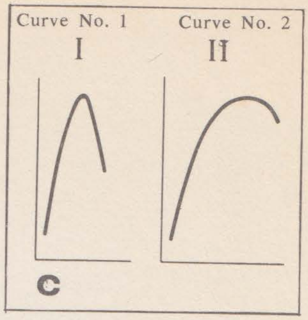
"You are to show the fly the shortest route for it to crawl to the drop of honey. The jar is twenty centimetres high and ten centimetres in diameter."

You will realise that it's fairly difficult trying to work it out by straightforward calculation; but if you "unroll" the sides of the jar to make them into one complete, flat surface, the problem becomes very much simpler.

The cylinder, when flattened out, becomes a rectangle with a height equal to the height of the jar, i.e. 20 cm., and with a length equal to the circumference of the jar, i.e. 10 cm. $\times$ 3.14 = 31.4 cm. Let us mark the positions of the drop of honey and the fly on this rectangle. The fly is at point *A*, being 17 cm. from the base of the rectangle, and the honey is at point *B*, at the same height as the fly and at a distance from point *A* equal to half the circumference of the jar, i.e. 15.7 cm.







To find the point at which the fly must cross the rim of the jar we draw a straight line from point *B* and perpendicular to the upper edge of the rectangle, and we extend this line to point *C* so that points *B* and *C* are at equal distances from the upper edge of the rectangle. We then draw a straight line between points *A* and *C*. Where this line crosses the upper edge of the rectangle is point *D*, and point *D* is where the fly should cross the rim of the jar. The result is that the fly's shortest route is given by the line *ADB*.

How a fly, knowing nothing about such diagrams and drawings, would actually find its way from point *A* to point *B*, is difficult to say. But for a person, knowing something about drawing objects on flat surfaces, the easiest way is to do it graphically, with a pencil and ruler.

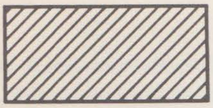
And drawings, real pictures, so to speak, are not the only things a technical person will need. Drawings are one thing, graphs are something quite different. The fluidity of their elegant curves, their sudden splashes, their crafty zig-zags and their unexpected rises and falls, all this can hide great discoveries, terrible tragedies, sparkling joy, momentary revelations and merciless failures. And do not think that there is an ounce of exaggeration in any one of these words.

For instance, if the curve of petrol consumption is running some five millimetres above expectation, or, as we say, *above standard*, then you can say for certain that your carburettor is over the hill. With such an over-consumption of petrol your transport funds will soon go bust. Your car will be lucky to make it from one garage to the next. You can insist that the carburettor is all right, by all means, but that it just happens to want setting properly. Of course. Do please give the jets a wipe, give the regulator screws a twist, then we'll see what comes of it, that is, we'll draw another graph.

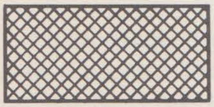
If a test pilot hands in a speed graph drawn like the one in *fig. a*, then you can tell him right away: my friend, it is high time for you to change your job. You wouldn't expect a saw-tooth graph like that from an ape taking his first flying lessons, let alone from a master pilot! Master pilots should produce graphs like that in *fig. b*.

And while we're on the subject of aviation, take a look at the two curves in *fig. c*. The uninitiated will say: one of them has a sharper turn than the other.

A Few Standard Symbols...



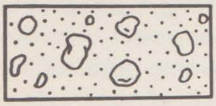
Metals



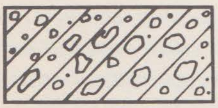
Non-metal materials

Timber cut across the grain

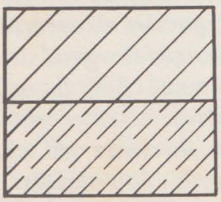
Timber cut along the grain



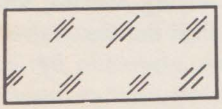
Concrete (not reinforced)



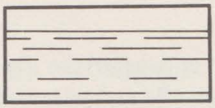
Reinforced concrete



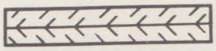
Special bricks (fire-proof)



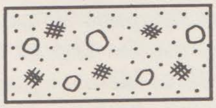
Glass and other transparent materials



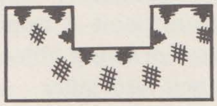
Liquid



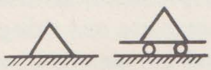
Plywood



Artificial ground



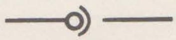
Natural ground



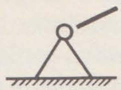
Immobile support
Mobile support

Fixed joint

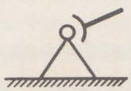
Variable joint



Ball and socket joint



Two-dimensional variable joint on an immobile support pivot

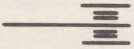


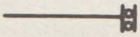
Ball and socket joint on a support

Radial ball bearing

Radial slide bearing

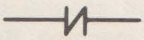
...or a Bit of the Language of Diagrams

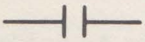

Radial roller bearing

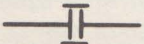

Supporting ball bearing

SHAFT JOINTS


Sealed


Elastic


Variable

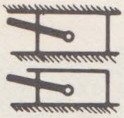

Sleeve joint

SPRINGS

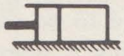

Compression

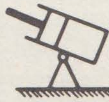

Tension


Conical


Runner in fixed guides


Fixed drum with connecting rod


Fixed drum with piston rod


Rolling drum


Water geyser


Drinking fountain

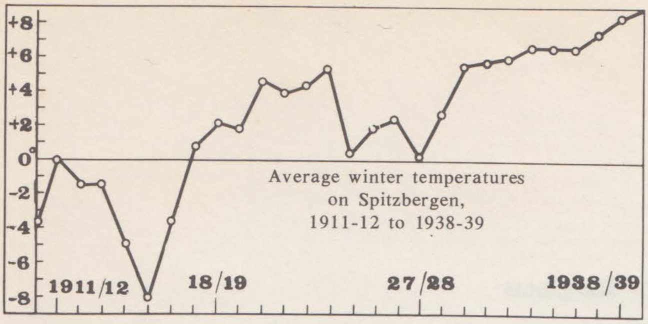

Water tap


Laboratory tap

BOLT-HEADS

Form	Protruding	Countersunk			Half Countersunk		
Position	Both sides	Near, visible side	Far, blind side	Both sides	Near, visible side	Far, blind side	Both sides
Standard Symbols							
							

4—76



Average winter temperatures on Spitzbergen, 1911-12 to 1938-39

Full stop. An experienced pilot on the other hand, without even bothering to look at the numerical details on the axes, will take one look at the characteristics of the two curves and will say straight away: the first 'plane would be hopeless in a spin. The sharp turn of the first curve is a sure sign that the 'plane could drop into a sudden spin. And besides, if you are trying to land the 'plane in some hole that's pretty tight, then you'll have to be careful because it won't stand much levelling out in the air. Most probably it doesn't like a side wind, and in general it will need very careful handling. Basically, it's an extremely demanding machine. But the other one is quite pleasant and good-natured.

For the next graph I took the average winter temperatures on the Arctic island of Spitzbergen between the winters of 1911-12 and 1938-39.

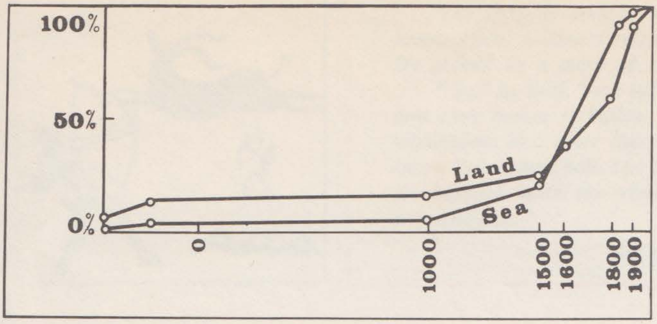
Looking at the original list of numbers I could have told you only one thing: it's not really as cold on this Arctic island as I had imagined. Many years the average winter temperature was even above freezing.

But when I'd got my piece of graph paper, written the figures for temperatures on the vertical axis and the various years on the horizontal, and drawn the relevant points and joined them up, then what I saw was not just a set of individual temperatures, but a process, an on-going series.

In the twenty-seven years taken, from 1911-12 to 1938-39, there was a noticeable "warming-up" on the island. The last of the coldest years was 1917, and since then the average temperature has not once dropped below freezing. True, the years between 1919 and 1929 were unsettled, one year warmer, one year colder, but in the ten years to 1939 the picture finally settled down and the warming up process became permanent.

Everyone, and not only a specialist weather forecaster, can draw conclusions like that from a graph; and it is important, because a graph is simple, clear and easily understandable.

Then there is the next type of graph, a different kettle of fish altogether. The vertical axis shows the percentages of the earth's surface which has been explored, and the horizontal shows the passage of time. So far this graph is fairly similar to the last one. But there is a significant difference: the upper curve



shows the exploration of the earth's land surface, the lower shows the exploration of the seas. Now let us read the graph and set out our conclusions:

1) before 1,000 AD man was not particularly inquisitive about the planet on which he lived. Journeys by land were far more frequent than by sea, but what was known about our planet, both by land and by sea, was ten times less than what was not known;

2) in the next five hundred years man's explorations were on the increase and the sea-venturers almost caught up with their land rivals in terms of opening up new areas. One indirect conclusion from this is the noticeable increase in the number of ships built in the twelfth to fourteenth centuries;

3) the middle of the fifteenth century saw the sea-venturers finally catch up and then overtake their rivals on land. The sharp rise of both curves also indicates the intensification of the search for new space on our planet;

4) by 1900 the sea-farers had discovered just about all there was to be discovered, and although the exploration of dry land was lagging a little way behind this too was nearing completion;

5) in the twentieth century man has finally been able to draw the most accurate and detailed description of his home — the Earth. He has explored everywhere, both by sea and by land.

A near relation of the graph is the diagram. A diagram can answer many of the questions put by an inquiring mind, it can answer clearly and persuasively.

How to see the relative surface areas of the Pacific, Atlantic and Indian Oceans? It seems to me that there can be no better way than to show their surfaces as squares placed one on top of the other.

Graphic representation of objects, events, phenomena and the interrelationship between two sizes is a matter of necessity for specialists in all fields: scholars, doctors, meteorologists, sailors, pilots, historians, economists, and anyone involved with technology.

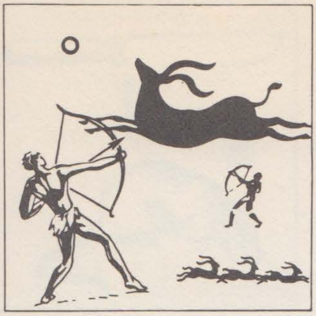
In Praise of Our Oldest Teacher

You are probably well aware that our very first teacher was nature itself. About eight hundred thousand years ago it was nature that placed a stone in the hand of one of our most distant forefathers. Today we call this stone an eolith, and we marvel at the imagination and persistence of the first hunters who realised the advantages of working the stone to suit their needs. Times changed, and man advanced to the stage of making axes, became aware of "natural" fire started by the forces of nature, diversified his simple working tools, and all the time he was learning from the things around him.

Archeologists have learnt to "read" the past from circumstantial evidence, and with their help we can imagine and understand a great deal about the beginnings of technology.

An ancient hunter is making his way through the undergrowth, his flesh whipped by the branches of shrubs as he brushes them aside, it is painful as the blood trickles from his scratches.

But one fine day — yes, a very fine day — it occurs to him: what if I bend the branches back deliberately, attach a sharpened stick to a branch and then, when an animal comes to take a drink at the watering hole, let go? The branch should spring back into place, the arrow will fly off, and then... At last man realises that he didn't suffer the forest's lessons in vain. And so the ancestor of the bow was born, the ancestor of weapons that have not to this day been made completely redundant. Of course, the bow still had a long way to go along the road of evolution, it will have its own history, but its first rough draft was designed from the promptings of nature. A chance occurrence plus a chance occurrence, plus many, many more, all went to make up a phenomenon. And the most remarkable thing is that man did not let the phenomenon pass by unnoticed. In the language of modern technology this phenomenon is known as the elasticity of matter. But now let's look at how the phenomenon progressed through the years: in the beginning, as we have seen, there was the branch that drew blood, then the bows of the earliest hunters, then came a long period in which the bow (up to and including the crossbow) was improved more and more; and from the development of the bow there were by-products — slings, catapults and other such-like machines. The elasticity of matter came to be used more widely,



The strip he coiled carefully, till it disappeared in his hand. Then, suddenly releasing it, it sprang straight again. He picked up a piece of blubber.

"So," he said, "one takes a small chunk of blubber thus, and thus makes it hollow. Then into the hollow goes the whalebone, so... After that it is put outside where it freezes into a little round ball. The bear swallows the little round ball, the blubber melts, the whalebone with its sharp ends stands out straight..."

Jack London, "The Story of Keesh"

more ingeniously, and ever more resourcefully. And the earliest springs were really descendants of the ancient bow.

Seeing rocks hurtling down steep slopes, and giant trees falling and destroying everything in their way, man did not discover (he wasn't that well advanced) the laws of gravity, but what he did notice was that the bigger the falling object, the greater the devastation it caused. But even a comparatively small stone could do no less damage if it fell from a sufficient height and managed to get up a fair speed. And this particular observation had a number of most useful consequences. Hunters and warriors began to use missiles with long handles; and later the power of falling objects was used in an increasing variety of ways: traps set using a finely balanced weight (i. e. one that will fall with a slight touch), devices for throwing rocks, battering rams, etc., and their more peaceful cousins, such as blacksmiths' hammers, water-lifting constructions and, much later, the first machines using levers.

Taking a look at the development of "the weight put to work" you will of course come to the familiar conclusion: nature's lessons, multiplying, accumulating and being perfected by the experiments which man himself carried out, always led our forebears to a knowledge of (initially), and an understanding of (later), new phenomena. This process was repeated many, many times and in many, many different ways.

We know that the first vessels (dishes, jugs and the like) were woven from pliable twigs, then coated with clay and left to dry in the sun. And one day, probably quite by accident, one such vessel fell in the fire and ... man discovered the path leading to the art of pottery. Time goes by, and with greater experience fire begins to be used in more and more technological processes. It was probably potters who first smelted metal, beginning with copper...

Man still had no idea of the nature or properties of ores, or even of where to find them. And again our favourite process comes into operation: a chance occurrence plus a chance occurrence, plus many, many more...

I mention this process not because it is interesting in itself, but for a very different reason: experiment plus experiment, plus many, many experiments, and a lot of thought given to the results — this is the highway of all science, of all technol-

ogy, of all advancement. And the young of today, if they want to be creators of progress, and not just idle consumers of its successes and achievements, must master this process.

But, today's young Archimedes may object, surely in the million years it's been on the earth mankind has already robbed nature's storehouse clean, tasted all its secrets, learnt all its lessons and passed all its tests?

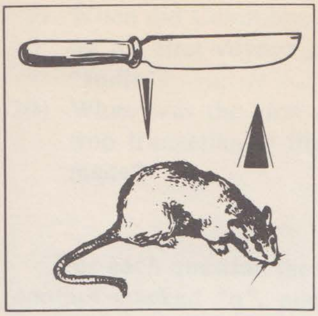
At first sight it would indeed seem that if there are any secrets left unfathomed then they are hidden deep inside nature's materials, and to find the key to the unknown it would take an atomic scientist or someone making a study of living cells and capable of drawing out their invisible and silent particles: but this is far from being the case. Nature still has infinitely more secrets than you could imagine.

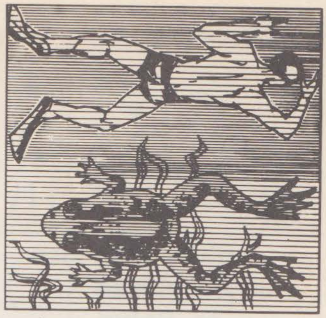
It is not long since we began making self-sharpening knives. And where did we get the idea from? From rodents' teeth. If we make the centre of the blade out of a piece of hard steel, and then cover it with several layers of iron (which is not as hard), then the edge of the blade will wear away unevenly, the softer part more quickly, the harder part more slowly. And the longer the knife is used, the sharper it will become. We took the design for self-sharpening knives, as I say, from nature, and we didn't have to split the atom to do it, we simply had to look a little more closely at the teeth of a mouse.

Every year thousands of migrating birds cross oceans, continents and seas to find their way, unerringly, to their nesting places. Man has developed navigation systems that are automatic and of the most accurate and dependable construction: they can help us to find, anywhere in the world, an object the size of a football. But what a size these systems are! Just look at even our best navigational system and see how far behind that of an ordinary swallow it is! Yet another area in which engineers have a lot to learn from the secrets of nature.

It is not that long ago when divers were first fitted out with rubber flippers. And of course the prototype of this simple "invention" existed even before man was seen on the earth. We need only recall the webbed feet of the common frog.

In my examples I have deliberately mixed the most straightforward with the most





complex, so that everyone can realise how much we still do not know about our world. What a variety of shapes and sizes remains to be discovered from the hidden storehouses of our planet! A man of technology must never skip the lessons of his oldest teacher — nature. And these lessons are best learnt at the beginning, when the mind's perception of new ideas is especially keen, when its curiosity about everything around it is still strong, and when it is easiest to be intently observant and meticulous.

A water-spider runs across the surface of the water, its slender legs sliding over the mirror smoothness like skis. Take a look at the spider. Have a think, why it doesn't sink into a watery grave. And then maybe you will find a way to copy it.

Bees build their amazing homes with matchless precision. Their honeycombs are not something to be overlooked, they are engineering constructions from which we can learn much. We have honeycomb radiators, for instance, and perhaps this design can provide us with yet more technical "inventions".

A tiny blade of grass forces its way up through the asphalt surface of a path. Don't trample it underfoot. Stop and think about it: what sort of power must this simple blade of grass generate? Perhaps it holds the secret for super-powerful hydraulic jacks, overhead cranes and drilling equipment.

Have you noticed the similarity between an aeroplane taking off and a bird taking off? The aeroplane raises its undercarriage into its fuselage, and the bird tucks its legs up under its belly!

The air-bladder of a fish allows the common herring perfect manoeuvring ability under water and keeps it on an even keel. And don't our nuclear submarines maintain their equilibrium in exactly the same way?

You've seen a ball and socket joint: does it remind you of something? It always reminds me of a person's elbow joint.

Something to Think About, Problems to Solve

16) You probably have some idea about what the centre of gravity is. If you do, then try to find the centre of gravity of an ordinary long-handled brush (or, perhaps, a ski stick), without using any apparatus or gadgetry, but only using your own hands. It is not, in fact, that difficult, it's just a matter of knowing how to set about it.

17) If you're setting off on a hike for a few days, it's always a good idea to have some matches constantly "ready for action". Even if you go for an unexpected "swim" in a mountain stream, or if you get soaked in a rain-storm, your matches should always stay dry and should light at the first attempt. What is the easiest way of ensuring that this is the case?

18) We shouldn't make mistakes but, unfortunately, it is something everyone is prone to. It is therefore important to be able to spot mistakes (your own, or other people's). Try to find the error in the following equations which, it would seem, prove that $7 = 5$.

$7\,(7 - 5) = (5 + 2)\,(7 - 5)$ OK? If we remove the brackets: $49 - 35 = 35 + 14 - 25 - 10$. If we take the 14 to the left-hand side of the equation, and change the sign accordingly: $49 - 35 - 14 = 35 - 25 - 10$. If we take the highest factor on each side of the equation: $7\,(7 - 5 - 2) = 5\,(7 - 5 - 2)$. And dividing each side by the common factor we have the answer:

$$7 = 5\,?$$

19) You have in front of you a board with a list of questions and answers:

1)	What is the height (in metres) of Chomolungma?	4807
2)	The height (in metres) of Mont Blanc?	8848
3)	When was Napoleon born?	5625
4)	When was the great Russian poet, Alexander Pushkin, born?	1769
5)	When did the first successful expedition reach the North Pole?	1799
6)	And the South Pole?	4225
7)	Can you square 75 in your head?	1908
8)	And 65?	1919

9) When did Columbus set off on his first voyage to "India"? 1492

10) When was the first non-stop transatlantic flight made? 1911

For each question there is an electric contact marked "q", and for each answer there is one marked "a". You also have a battery, a light bulb (out of a torch or bicycle lamp) to verify the electric current, and two floating contacts "A" and "B". Have a good think about the arrangement and try to answer the following questions:

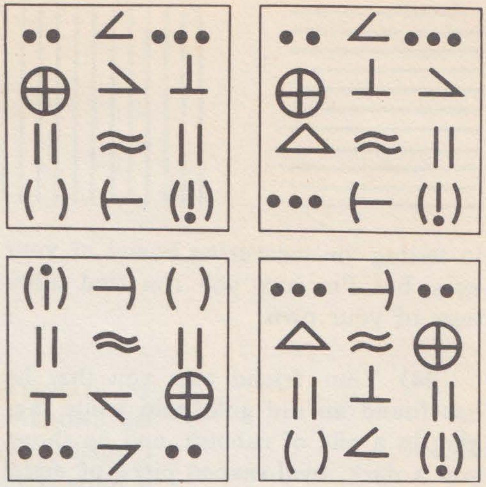
1) How would you join the contacts behind the board so that the bulb would light up only if the correct answer is given to a question?

2) How would you draw a diagram of the reverse side of the board to show the "path" of the electric current?

3) How would you make a note in digits of the correct connections between the contacts?

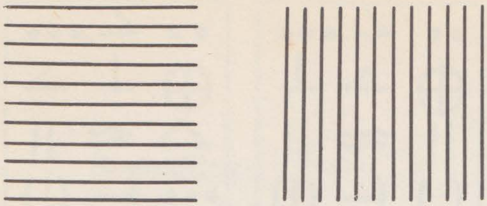
20) You have been asked to take out a pole from the ground (let's say a pole used to hold up a volley-ball net). How would you set about it most simply, but without digging up the ground around it or spoiling the pole by hewing, sawing or drilling it?

21) Set out below are four drawings. Can you say, taking only 20 seconds and not one iota more, whether they are all different, or whether two or more of them are identical?



22) Powers of observation and a good photographic memory are useful qualities to have in the world of technology. The following, then, is a little test of your concentration. The two pictures below are totally different, but in 30 seconds or less can you find the seven objects which appear in both of them?

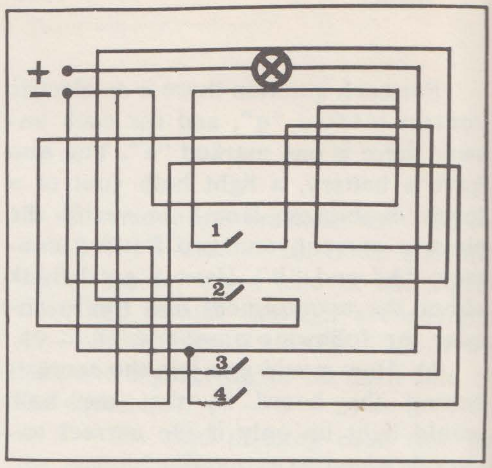
23) An engineer needs a good eye for sizes and distances. Look at the two squares below, and try to say which is the larger. With this one exercise alone you won't get enough practice



in testing the measuring power of your eyes, but I'm sure you can find other tests of your own.

24) Your friend tells you that he has found an old gold coin while digging in a pile of rubbish, and he shows you a dark, oval-shaped piece of metal with some indistinguishable writing on it. How can you tell whether the coin is gold or not (but without doing any damage to it, just in case it is a valuable object belonging in a museum)?

25) Take a look at the diagram of electric circuits below and decide which button you should press to make the bulb light up.

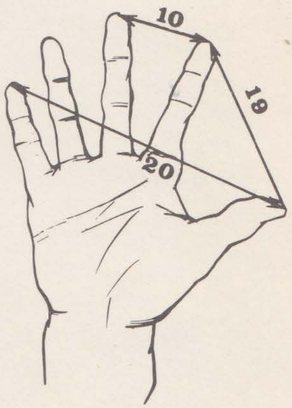


Some Useful Hints

People sometimes say: "I know that like the palm of my hand." And everyone, of course, thinks he knows his hands so well, knows them like ... "the palm of my hand". But is that really the case? Can you tell me, then, what is the largest possible distance between the tips of your thumb and little finger? Or between your middle and index fingers? Or between your thumb and index finger?

I can tell you the size of *my* hand:

a) from thumb to little finger — 20 centimetres;
b) from middle to index finger — 10 centimetres;
c) from thumb to index finger — 19 centimetres.

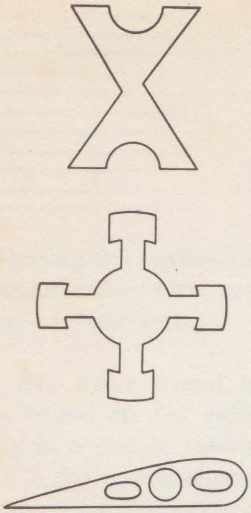


But what's the point of knowing all this, what can it do for us?

Knowing the size of your hand *does* have a point: if you have to decide, even if only roughly, whether a certain plank or pole will do for something you're going to build, but you don't have a ruler or measure to hand... Then you can use your hands. Let's say you measure out six "strides" along the plank, and your "stride" (thumb to index finger) you know to be 19 centimetres, then you have a plank approximately $19 \times 6 = 114$ centimetres long. So you can be fairly certain that you can make something a metre long out of it.

Finger measurements are also extremely useful when you are dealing with maps, plans and diagrams. Of course, you can't measure precise distances just with your fingers, but they will always give you something to work by.

Just in case, there's another very simple and very useful measurement you may like to know about for smaller objects: a match-stick. The standard match is just over four centimetres long and two millimetres thick.



Many future engineers and mechanics begin their technical activities by making models. And for these models they often have to prepare a large number of identical parts. Perhaps twenty or thirty wing ribs for an aeroplane, ribs that are alike as twenty or thirty peas in a pod; or maybe the task is a series of ribs for the hull of a ship, or a whole pile of tin brackets for use in all sorts of ways.

So as not to waste time measuring out each separate part, and at the same time making each part more accurately, I strongly suggest you use a template.

A template can be made from a piece of stiff cardboard, a piece of lightweight tin or a piece of plastic, and you simply make it as a "spare" copy of the real parts you require. Then all you do is put the template on whatever you are going to cut the real parts out of, and draw round it. And that's it. This way you do away with all the re-measurings of each part, and if you want to check the size and shape of the real part that you've cut out, you measure it against the template and you'll see at a glance where it needs rounding off, or filing down, or whatever.

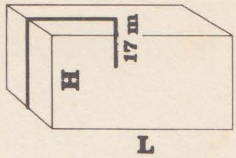
When a teacher says to a class of small children: "Now take your pencils and write this down", that means that he is going to tell them something that it is important for them to remember. So the teacher will simply write something on the blackboard, and the class will write it down word for word. Later still the teacher just dictates the more important conclusions. And finally, the teacher will give a lecture with no indication of what should be written down: the more grown-up pupils and students will work out for themselves what they should write, and what not.

But things quite often go wrong: a person tries to write down everything, and finds he can't do it. There are two disadvantages in this: one is the waste of energy on what he does write down, the other is that he doesn't hear everything the lecturer says. Therefore he doesn't write down what he should, and he doesn't remember what he should.

So my advice to older pupils is to learn some sort of shorthand using standard symbols. It won't be in the realms of stenography, but with practice it will help you to take down lecture notes up to three times more quickly than in longhand.

For example.

"The height of a building is 29 metres, its length is 60 metres, and we wish to run a television cable perpendicularly up the side wall from the ground level and then, parallel to the building's length, across to the centre of the roof and down into the building for a distance of 17 metres. What length of cable do we require?"



The first thing to do is to draw a diagram of the building. Note on it the height (H.), the length (L.) and the length of the cable (L_1.). (The symbol for perpendicularity is $\perp$, and for parallels it is $\|$.) And the whole problem will be set out in a small diagram and two lines of text.

My friend Lyosha dreamt of having a bicycle for over three years. And there was always something to stop him getting it. First there was his father who said he was too small to have a real two-wheeler; then there was his mother who didn't want him tearing around the town on a bicycle because there was so much traffic.

But finally, it seemed, he would have his bicycle: his father gave his assent, his mother relented, and the money for it was to hand. Fine, except that another obstacle, totally unexpected, came to the fore: what make of bicycle would he buy? There are so many to choose from.

The shop-assistant was all in favour of the Orlyonok.

Lyosha's friend Slavik said the only one to buy was a Kharkov; Slavik himself had a Kharkov of course.

Shurik, a champion cyclist living nearby, recommended a Turist.

Lyosha was at a loss.

And then his grandfather suddenly came to his rescue:

"Lyosha, go to the bicycle repair shop and ask the man there which makes of bicycle he has to mend most, and which he has least to do with. Are you with me?"

I reckon Lyosha's grandfather was a pretty shrewd fellow.

And since we all have to seek advice at one time or another, I strongly recommend that you choose your advisors carefully; it can make a big difference to whatever it is you are trying to achieve.

And a word more about advice: don't go giving advice if you don't think you are sufficiently knowledgeable, or if for some other reason you are not in a position to be totally objective.

It is, of course, quite nice to have clear, legible handwriting, just as it is undesirable to write in such hieroglyphics that you yourself cannot make out what you have written. But if you have written words and sentences untidily then a bit of common sense may help you: starting from the letters that you *can* read, you can often guess at the ones you cannot read by working out what letters will "fit" to make up proper words. But if it's numbers you've written untidily, then you have a real problem: it is easy to mistake an untidy 2 for a 7, a 3 for an 8, or a 5 for a 6.

I would strongly advise anyone who wouldn't get ten out of ten for calligraphy to be very careful about writing numbers. House No. 3, for example, isn't even on the same side of the street as house No. 8, and using a 70-volt electric current in place of a 20-volt current can be quite dangerous.

Vladimir Grigorievich Shukhov was not just "an engineer", he was a whole epoch in the development of engineering at the beginning of this century, and his name is mentioned with the utmost respect in Russian engineering circles. Without trying to set out his entire biography, I would like you to consider one or two "chapter headings" from his astonishing life.

In 1875, at the age of twenty, *Shukhov was the chief engineer in the construction firm of A. Bari. One of his earliest discoveries was the use of a pneumatic pump for the extraction of oil from the ground, rather than the traditional sludge pump. Then he designed steel reservoirs for oil and the various products manufactured from it. He built oil pipe-lines and developed a means of pre-heating the oil before pumping it through the pipes. He constructed barges for carrying oil in bulk, vessels which we now call tankers. But that's not all. Shukhov designed jets for dispersing fuel-oil using high-pressure steam. He improved the method of "cracking" oil — its distillation under pressure and at high temperatures.*

This, you might say, was just one "volume" of Shukhov's activities. Another "volume" would deal with his innovations in the designs of vaulted ceilings, towers, lighthouses and radio masts.

And the "appendix": boilers, pumps, bridges, blast furnaces and gasometers.

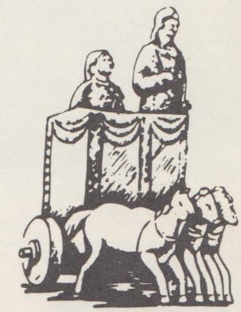
Vladimir Grigorievich Shukhov lived eighty-six years of an amazingly intense and hard-working life. And all his years were an unceasing advance into the future.

Dates on the Calendar

12,000-7,000 years BC

Man begins to use a bow and arrow: the arrow's tip is made of sharpened flint. It is the beginning of the age of microliths, the technical name given to the head and feathers of arrows. Microliths have been found in great numbers on the sites of primitive man's settlements.

7,000-4,000 years BC



Archeologists have found traces of pot vessels from this period. Tools and weapons become more varied and more intricate: stone axes, chisels, maces, and flint knives, scraping tools and arrows.

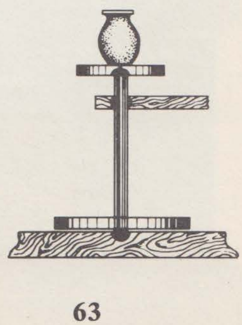
Man begins to build pile-dwellings.

Around 4,000 BC the Egyptians manufacture bricks, and the Indians invent the wheel.

4,000-3,000 years BC

The first copper tools are smelted. Stone implements continue to be used widely, but man also learns to work copper without heat.

The first clay huts are built, and in the Orient the potter's wheel is invented.



3,000-2,000 years BC

Sun clocks are in use in Egypt, India and China. Bronze tools and weapons are widely used.

2,000 years BC

Invention of the hubbed wheel.

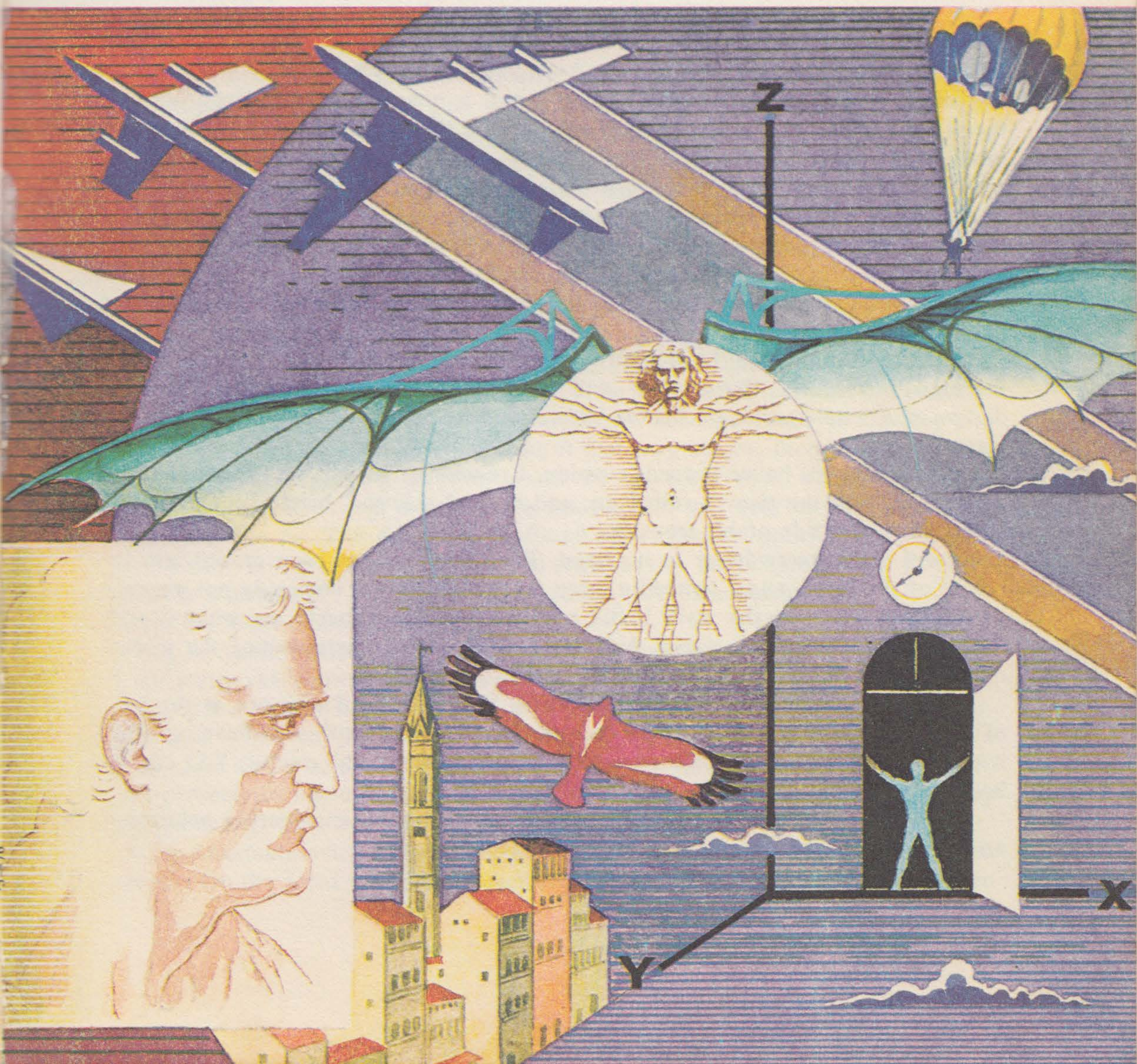
1,400 years BC

Iron is forged in Armenia, and a means of tempering its surface is discovered.

1,000 years BC

The beginning of the Iron Age in Europe.

3



Two Unforgettable Encounters

I have been lucky: in my life I have met many engineers, designers and inventors. I have talked with many such people at various times, some quite famous, others humble beginners. Listening to them and watching them, I have tried to imagine what sort of person a real engineer should be. But it is not an easy question to answer: there are unlikely to be two identical engineers in the world, just as I cannot really imagine two totally identical people in any other profession. Having met so many people I have been able, to a certain extent, to form a composite portrait of the "ideal engineer", and perhaps one day I shall put it down on paper. In the meantime I would like to present to the reader two very different and very remarkable men.

I am not going to write their biographies, I am just going to tell you about two particular conversations.

Semyon Alexeyevich Lavochkin was a well-known figure in Soviet aviation. During the Second World War and afterwards he was responsible for the design of a whole series of fighter 'planes which have become legends in Soviet history.

I arrived at his house towards evening. I remember he was wearing a starched white shirt with the sleeves rolled up, and he had a broad, bright blue General's stripe down the side of his trousers.

There was a screwdriver in his hand. The television had been moved into the centre of the room, and I noticed a large mirror which was obviously not where it should have been on the wall. It did not immediately occur to me what exactly Semyon Alexeyevich was doing. And then I realised: he was adjusting the picture on the television.

"Have you ever noticed," he said, "how the adjusting knobs are at the back of the set, while the picture, quite reasonably, is at the front? You have to adjust it somehow, so I turn the knobs and look at the picture in the mirror. You can see how it works."

With the television fixed, we began talking about the engineering profession, about what he thought was the most important part of it.

And Semyon Alexeyevich said:

"A good engineer differs from a bad engineer, first and foremost, in that the good engineer knows more and can do more. When I say 'knows', I don't mean the knowledge they teach in institutes and colleges, nor do I mean the knowledge that shows the technical ability of a specialist in a particular sector of the profession. What I have in mind is a much wider knowledge. For example, if the designers of that machine over there" — gesture in the direction of the television — "had even the slightest idea of the principles on which an aeroplane cockpit is designed, then they would not have come up with anything like that.

"Being able to do a great many things doesn't just mean in your own little world. It is a good idea for an engineer to be well-versed in trades which are not his own."

I am giving you Lavochkin's words as I wrote them down at the time in an old notebook. I remember we talked for a long time about the range of specialists, and I made the following notes:

"An engineer should begin very early; around the age of seven. He should learn to saw, to plane and to glue things together. He should acquire a feel for his materials. If he breaks one of his toys, well, these things happen. If he mends one of his toys that he has broken, so much the better. He must develop his curiosity and he must learn to do things with his own hands.

"Have you seen a snow-plough — not one that just brushes the snow aside, but one of those that gathers it up and throws it onto an adjacent lorry — now there's a miracle on wheels for you. Let us admire it! You should enjoy every miracle, otherwise you won't be an engineer, you will just be a man with a trade, a handyman. An engineer should learn to draw. That is imperative! He may not turn out to be another Van Gogh, but it is important for him to be able to set his ideas out graphically. To think in terms of visible pictures of non-existent objects is the privilege of a good engineer. Also he needs to develop the ability to think boldly: if no-one has done it that way before, then that is the way he should think of trying it! You won't do anything new where everything has already been done and everything is known; you will only be able to dot the i's and cross the t's. The new is to be found on untrodden paths."

All his life and in all his work Semyon Alexeyevich Lavochkin proved just how true these words are: "The new is to be found on untrodden paths."

And the second short meeting.

Oleg Konstantinovich Antonov was also a leading Soviet aviation engineer, and was for many years the head of a large aircraft design and construction workshop. In his office one day he was talking to a younger colleague, not about an aeroplane itself — the subject of the conversation was one of the workshop's own 'planes, used for crop-spraying — but about the aeroplane's auxiliary equipment. I was present during the discussion purely by chance but, of course, I did try to remember all that was said.

Oleg Konstantinovich handed the young engineer a magazine, I think it was *Ogonyok*. On the front cover was a picture of the crop-spraying aircraft; two men

in white overalls and gas-masks were standing on a ladder and pouring chemicals into the aeroplane's hold. Under the picture was a caption, something like: "Flying protection for our fields".

I should perhaps explain that this incident took place some years ago, at the very beginning of the 1950s.

"How can you look at it so calmly? It's a crying shame," Oleg Konstantinovich was saying. "And it's uneconomical. In the air for half an hour, then it takes an hour to reload. And what an archaic way to load! An aeroplane and a horse-drawn cart are not really compatible. How are you getting along with the automatic loader?"

The young engineer explained in some detail that the conveyer-belt dry-goods loader was not such a straightforward machine. It was coming along, but not as quickly as could be hoped. The main problem was that there were no specialists on hand to help out.

"We have had to start from scratch; to carry out experiments, make tests and see how things go."

Oleg Konstantinovich listened patiently. To give him his due, he was a good listener. And when the engineer had finished his business-like and extremely thorough report, Oleg Konstantinovich said:

"If you go and watch millers at work you will see that they have been dealing with dry goods all their lives, it is second nature to them. Ask their advice. A good engineer should know where he can find what. And don't be too proud; we may be building aeroplanes but we can still take our hats off to millers. People who do unnecessary work are either fools or very naive."

The young engineer left the office. It seemed to me that he was not very pleased by his chief's parting words, but perhaps I was wrong. Oleg Konstantinovich continued his theme in conversation with me:

"An engineer must be aware of all new developments in science. It is, however, no less important to know what has been done in the past and what is being done alongside you. An engineer should also be an economist, he should never forget that speed and economy are the watchwords."

Oleg Konstantinovich was particularly interested in problems of an economic nature and he explained in great detail how ticket prices were calculated for aeroplanes that had not yet been built, in service on routes that were not yet in operation. He talked about the best fuselage dimensions for carrying cargos too large to fit into railway wagons. And then, I don't remember how, the subject of conversation changed.

"An engineer's production capacity is in direct proportion to his ability to 'switch off'. I am always glad to see engineers playing some sort of sport, going fishing or tearing up a mountain. Physical courage and spiritual courage heighten the coefficient of useful activity.

"An engineer who is nothing but an engineer is a poor engineer. An engineer should never forget that time passes. What is excellent today, will be only

In volume thirty-six of the Larger Soviet Encyclopaedia the entry for Wilhelm Conrad Roentgen and his work extends to 24 (twenty-four!) pages. An honour which is given to few scholars of any age or of any country.

I would like to quote just three lines from these pages: "An engineer by education, Wilhelm Conrad Roentgen completed his Polytechnic course in Zurich at the age of 21; at 23 he successfully defended his Ph. D. thesis."

satisfactory tomorrow, and in a year's time it will probably be worse than useless. Time is dearer than money."

As I have already mentioned, this conversation took place a long time ago. But I was at an airfield recently and I saw an Antei, one of the largest aeroplanes in the world; I recalled my talk with Oleg Konstantinovich Antonov and I thought to myself: "His workshop was aware of time, appreciated time and did not waste it; but more than that, it can overtake time and leave it far, far behind. It is an excellent example for all engineers, both current and future."

Two encounters, and a few pages in a notebook. And a feeling of restlessness that will not leave me. Why? It is not at all easy to put it into a few words. Perhaps it was after these two encounters that I first began to wonder what sort of person an engineer should be. I realise that standards of human personality cannot be set — so many people, so many different characters, individualities and temperaments — but in the infinite variety of features and characteristics there are probably some common professional signs and tokens, and it is these which we should study, summarise and understand.

It is impossible to teach someone to be a "second Lavochkin", or a "second Antonov"; but it is possible — it is not only possible, it is absolutely necessary — to teach young engineers the high standards and strict work-practices of Semyon Alexeyevich, and to teach them to follow his example by widening their horizons.

I have mentioned these two encounters in particular, not because they in any way exhaust the subject in hand, but because they shed a definite and most instructive light on the question of what sort of person an engineer should be, what he should aim for in life and what he should in no circumstances ignore. There's nothing more important, when mapping out a path — any path — for yourself, than finding the right direction at the very beginning. The right direction is the basis of your route: true, you will almost certainly have to make changes to it as you go along, but without the right direction at the outset you cannot hope to follow your path.

I shall end this chapter with the words of Semyon Alexeyevich Lavochkin:

"A person cannot choose what he looks like, but he does have a choice in something more important — his character. I am convinced that a person can have the personality he wants.

"From his very childhood a person should teach himself not to give up in the face of difficulties, but to finish what he starts. This will become a habit, and when he grows up he will have a magnificent quality — persistence."

And If We Come Down to Earth?

As I write I hear an impatient reader's voice saying:

"What you've said is all very well, and it's possibly very interesting and worth thinking about: take a look into the past — why not; don't ignore the bicycle, literally and figuratively — fine, I'll remember that; get used to reading plans, learn the language of technology — I quite agree. But what about a *practical* beginning? Like, what do I do tomorrow?"

It is not easy to answer a question like that. It is not an easy question to answer because I would have to know exactly the sort of person I was talking to. It is probably impossible to formulate a universal set of instructions for all amateur technicians, for all future engineers, designers and inventors. And what is indispensable to one may well be wasted on another. To be able to answer the impatient reader's question, I would need to know his age, his general background, his interests, his character, and many other things besides. And so, moving over from the realm of the general to recommendations of a totally concrete nature, I must warn you that what follows is not intended to be a specific path, but only a rough indication of the course you might take.

I think the first thing that a future technologist, whatever his area of operations, should do is to "lay his foundations", and the sooner the better. Time will not wait. Time is the most fluid and irreplaceable of raw materials. If you lose some money, you can always earn some more. If you fail a test the first time round, you can always take it a second time. If an experiment doesn't work out, you can always try it again. But you will never replace a wasted minute!

Like an accumulator you should store up knowledge. And remember that there is no "superfluous" knowledge!

Learn practical skills. What skills? Any! An engineer needs hands that can do things. Learn to use a saw, a plane, a soldering iron, learn to set up electric circuits, repair locks, replace windows, mend toys, fix soles on shoes, and all sorts of small jobs like this. The more you learn to do with your own hands, the better.

There is a certain passage from history which seems to me to be worth mentioning at this point.

One day — the year was 1776 — a man by the name of William Murdock entered James Watt's workshop; shifting uneasily from one foot to the other, he asked whether Watt needed a journeyman. Watt said he didn't, and Murdock was about to leave when Watt asked him:

"What is that in your hand?"

"A tub, sir."

"A tub? What is it made of?"

"Wood, sir."

"Where did you get it?"

"I made it on a lathe, sir."

"Where did you learn a turner's trade?"

"At home, sir. I made the lathe myself."

Murdock did not leave the workshop, he stayed there for the rest of his life. It was his hands that built practically all the machines and mechanisms that Watt designed.

I have not managed to find out very much about Murdock, but there is one little story I would like to recount.

He had built a small three-wheeled cart and one night he was testing it on a quiet road just outside the town. When the water in the steam motor began to boil, much to the surprise of the inventor the cart set off along the road, and it got up such a speed that the inventor was not able to catch up with it. Unfortunately, the local priest was walking along the road at the time, and when he saw a glowing, whistling object hurtling towards him, he thought he was seeing the devil himself. He raised such a noise that a whole crowd of people came running. The inventor tried to explain the secret of his "devil", but no-one would listen. The cart was quickly hacked to pieces, and its builder barely escaped with his life from the furious crowd.

I am not of course trying to say that Watt and Murdock are comparable: Watt was a genius, Murdock was a highly talented executor, whose masterly skills fully complemented Watt's endeavours.

The Russian scientist Dmitri Ivanovich Mendeleyev, the author of the Periodic

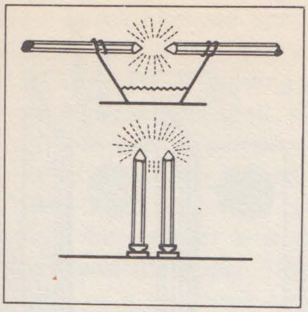


Table of the Elements, spent much of his spare time making high-quality suitcases. Konstantin Eduardovich Tsiolkovsky, one of the founders of space exploration, and a major theoretician of his time, was an accomplished metal-worker in his spare time and could vie with professional tin-smiths. Ivan Lyudvigovich Knunyants, a leading Soviet biochemist and a member of the Soviet Academy of Sciences, repairs and restores antique furniture.

These are, as it were, "historical facts", and the conclusion to be drawn from them is: whatever job you are doing, try to start it with a clear idea of what the end result of your efforts is intended to be. When you are making something, don't make it with the idea: "I'll see how it turns out this way"; make it in strict accordance with a plan, a draft or a drawing. Train yourself always to finish any job that you start. And if you get fed up with trying to adjust some awkward piece of metal till it's just the shape you want it, console yourself with the thought that no discovery or invention in the world has ever been made at the first attempt.

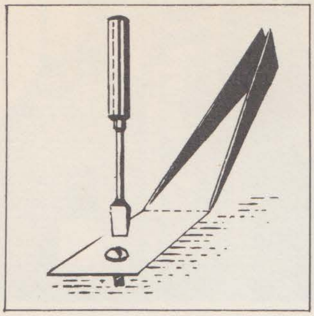
Thomas Edison used to say that genius is one per cent inspiration and ninety-nine per cent perspiration. And the man who experimented on 6,000 different materials to find the right one — and the only one (he was looking for the material from which to make the filament of an electric light bulb) had every right to make such a statement.

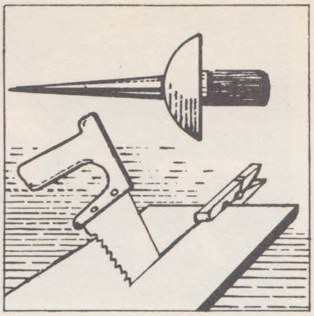
And the experience of Rudolf Diesel and Nikolaus Otto, who spent years making their engines, often remaking one and the same part hundreds of times, searching, searching unceasingly for the solution — this is further weighty corroboration of what Edison said.

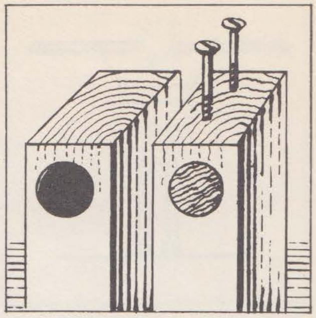
And then there is the classic example of Pavel Nikolayevich Yablochkov: the idea of using an electric arc in a light bulb was seen to be correct from the very beginning. But there was a snag: the electrodes burnt down fairly quickly; this meant that the space between them increased, and the arc was soon broken. A whole range of regulators was designed. They all worked, some better than others, but none of them satisfied Yablochkov.

"No, that's not the answer..."

And he tried more and more new variants of the solution.







Legend has it that he had quite despaired of finding the solution he was looking for, and he was sitting one day in a cafe in Paris, fidgeting with two pencils which were on the table in front of him.

"No, that's not the answer... But if ... if ..." Yablochkov stood the two pencils vertically, moved them closer together, and he saw the solution to his problem: "That's what we need, that's what we've been looking for."

True, he had to find a special coating — an insulation that would melt only slowly — so that the arc would not slide down the electrodes. True, he had to build an alternating-current generator so that the electrodes would burn down at the same speed. But this was merely detail. The main problem had been solved with two pencils — vertical electrodes!

Vertical electrodes — it really was a brilliant, a unique variant of the solution.

"Variant of the solution" is one of the most common concepts in the world of engineering.

A variant is a concept which is at once strict, capricious and extremely demanding. It was Michael Faraday who once said: "Hardly a tenth part, at best, of all one's conjectures, hopes, wishes and preliminary conclusions turn out to be justified!"

Accumulate experience. Accumulate constantly. For example, it may be you can never manage to screw in very tiny screws because they keep slipping out of your fingers at the crucial moment. And then your friend says to you: "If you get a strip of stiff paper you can push the screw through a small hole in one end of it; then you simply hold the screw in place with the paper 'handle', and when you have turned the screw two or three times you tear the paper away." That's a piece of good advice. It's a grain of invaluable experience. Gather it up.

It may be you are painting a wall, or a cupboard door, or any vertical surface like that, and you are finding that half the paint ends up on your hands. You might wonder about how you can improve the situation. If it occurs to you to put half an old tennis ball on the handle of the paint-brush, so as to "isolate" your fingers from the paint, then you will have made a small, though valuable discovery. It will be another grain of experience to gather up into your "store".

It may be you are cutting a large sheet of plywood with a hacksaw, and the loose ends where you started cutting are flapping about and getting in your way. If you think of holding these two ends together with a clamp or a peg to keep them steady, then be glad you thought of it. Be glad, and add this to your armoury of technical experience.

If you have turned an old bottle-top into a tool for scratching the scales off fish, that's no reason to think yourself an inventor deserving world-wide acclamation, but neither is it something to turn one's nose up at. It, like the half tennis ball and the paper "handle", is a result of a human mind in operation, it is the fruit of a reasoned approach to a given task.

In short, don't think that knocking a nail in properly is a trifling matter. In the final analysis all man's ability to work, improve his life and make technological discoveries — it is all made possible by an immense accumulation of experience, attention to detail and constant thought being given to ever new layers of knowledge. No-one of course will try to show that a kopeck is worth more than a rouble, but without a kopeck you won't have a rouble, let alone a hundred or a million roubles, just as you won't have an ocean without a drop of water.

By far the best source of experience is from taking a good look at the work of experts. Books, of course, are also a source of experience, especially reference books. And finally, your own work is a good source of experience, and not only when whatever you are making turns out a success; your mistakes and failures, I am firmly convinced, can have a positive effect as well. Positive, however, if these mistakes and failures not only get you annoyed, depressed and upset, but teach you something and show you how not to set about the job the next time.

How are you supposed to store experience? Do not rely on your memory. Your memory, even if very sharp, will always manage to let you down. Most people have to say, at one time or another: "It's gone clear out of my mind!" And so that things don't "go clear out of your mind", start using notepads, notebooks and a card-index system. Let's say you have found in a reference book or a magazine, or you have been told by one of your friends, how to make a certain type of glue quickly and easily. Don't rely on your memory, write down how to make it. Or if you are at the ice-rink and you see someone else's skates have an unusual fastening that it might be handy to remember, don't be lazy, make a drawing of it, even if only as a very rough sketch.

Gradually, as you build up a collection of useful and, most likely, ill-assorted bits of information, try to systematise what you have. How should you go about it? Well, let's say everything that involves the use of metal-working tools — vices, files, pliers and the like — keep together in one part of your notebook or in one section of your card index; everything involving priming, filling in holes, diluting paints, making up varnishes, and other jobs to do with decorating, keep in a different section, and so on.

Get used to accumulating, systematising and generalising your experience, and

you will be entering — without realising it — one of the most important areas of modern science, that of information technology.

Study the objects that surround you in your everyday life. Try to understand the basics of their construction, and take note of how widespread technical ideas are. I'll explain what I mean: you know what a simple brief-case lock looks like: a bracket, a spring and a lever. It's a simple and very useful device, isn't it? But have you ever noticed that the principle of this lock is also used for the fastenings on skis? I might add that locks of this type are widely used in aviation, and indeed in mechanical engineering generally.

But why should you really take any note of all this, what is so special about it? I will tell you. No engineer, no inventor, no-one at all in the world of technology, setting out to make something — a machine, a tool or instrument of any kind — will try to make everything from scratch; they will, automatically, use the inventions and achievements of their predecessors, they will use assembled parts, standard parts, and principles that have been tried and tested. That way it is far more beneficial and expedient, not to mention quicker. Which is why an engineer, present or future, should be able to look around and *see* things. It is not an easy ability to acquire, it takes practice; and the earlier a person starts practising, the less time and energy he will waste later in consequence.

The ideal solution to many engineering problems would be a gigantic engineering "kit", a huge selection of standard parts, assemblies and elements, which would allow us to make up a further multitude of components for all sorts of jobs. Construction kits, incidentally, are not only on sale in toy shops, but are in fact used in practice; modern buildings, for example, are constructed on the basis of building "kits", kits which are just a great deal larger and much more complicated than their toy counterparts.

And finally, one more piece of extremely important advice: when you are starting a new task, do try to see it through in accordance with a predetermined plan.

Let's say you are going to make an ordinary child's scooter into a mini-motor-scooter. Don't be in too much of a hurry to start making fixture brackets, running round the shops looking for headlights, or making an old oil can into a petrol tank. First of all it is absolutely essential to collect all the information you can (sizes, weights, materials, etc.) about the scooter and the engine you will use. Draw all the necessary parts, and work out what you will need to fix them all together. Try to find out how the job was done by other amateur technicians, if indeed the job has ever been done before, successfully. Study what your predecessors did; be a strict, unbiased judge of other people's work, this will prevent you from repeating other people's mistakes. After this basic preparation, make out a plan of the work to be done. Draw your future machine in its entirety, and make separate sketches of the parts you haven't got, make sure you know how these parts link in with one another, how they fit together, and only then, when you have everything sorted out on paper, should you start to make the necessary

bits and pieces. And when you have made them, you can construct your motor-scooter.

If you generalise this approach for use on any job you do, your "plan of campaign" will look something like this:

1) Find the preliminary solution.
2) Collect the necessary information, and evaluate it.
3) Make your final decision.
4) Begin your design and calculations.
5) Elaborate the details of your decision.
6) Prepare everything necessary for the job.
7) Construct what you have designed.

The suggested plan is not universal, and it is by no means the only one to cover all the situations you may come across, but it is, at least, better than any unsystematic approach to a job. And one further point: as you accustom yourself to working to a plan, you will be getting used to a logical, methodical solution to engineering problems. And without method there can be no real engineering.

The above plan is not a set of "rules", I am not personally in favour of "rules for all situations", but there are certain recommendations which it is worth bearing in mind when you start a job. These recommendations are based on a study of many facts in many characteristic situations: in short, they "reflect" life.

The majority of people suffer from a lack of time. Everyone would be happy to learn, make, achieve — but the snag is that they have no time. For those who wish to learn how to save time, and thus manage to do more than they have done so far, I list below ten recommendations, taken from a scientific text-book which, incidentally, fully agrees with what I have said above.

RECOMMENDATION ONE. In order not to waste time you should always know, at the very outset, what you wish to achieve, and how you intend to achieve it. In other words, when you start any job, try to picture your goal as clearly as possible.

RECOMMENDATION TWO. Always decide what your main task is, and concentrate all your efforts on completing it. If you have more than one "main" task, put them in some sort of numerical order, and don't jump around from one to the other. Begin with task No. 1, and only when you have finished it start on task No. 2, and so on.

RECOMMENDATION THREE. Set yourself a time limit for every job: an hour, a day, a week, a month, depending on the job's complexity and the amount of work involved. And always adhere strictly to your time limit.

RECOMMENDATION FOUR. Never say to yourself: "I'll have a go... I'll have a try... I'll have a think about it... I'll see if I can do it...", knowing that you really cannot do the job you are thinking of. You may already have noticed that it is a lot easier to say "yes" than to say "no", but you must be able to say "no", and to say it firmly and decisively.

RECOMMENDATION FIVE. Don't ignore your notebook or note-pad; don't

A man by the name of Thompson, a resourceful master-weaver, one day decided to redesign his weaving loom by leaving out two of the cogwheels. But he just couldn't work out how to do it. But then, as they say, he had a brainwave. And his brainwave came to him just as he was going to bed one night.

Thompson himself takes up the story: "Imagine my despair in the morning when I found that I had forgotten the solution that I had thought of the night before! For two whole weeks I walked round like a man possessed, and I couldn't think of anything else. Fortunately, the solution came to me again, only this time I wrote it down."

rely on your memory. A line of writing, someone's address for example, may save you several hours searching around and getting lost looking for the right house.

RECOMMENDATION SIX. When you listen, listen carefully; this way you will avoid many mistakes, and you will not have to ask people to repeat themselves. Remember that every mistake (and the job of putting it right), apart from anything else, is a waste of time.

RECOMMENDATION SEVEN. Try to have in hand a supply of "consumables". To go out and buy, in one go, a pencil, a biro, a notebook and glue, for example, may take you twenty minutes. But if you go out separately for each, it could take you perhaps an hour and a half.

RECOMMENDATION EIGHT. Be on the look-out for "reserves" of spare time: while you are waiting for the kettle to boil, you might have time to do your morning exercises; if you are going to the football on a Saturday afternoon, your journey could well be long enough to give you time to read, say, twenty pages of a text-book.

RECOMMENDATION NINE. Never do anything on the principle that "well, that's what everyone else does". If your friend is prepared to spend hours kicking his heels in the street, that is no reason why you should drop what you are doing and go and join him. This recommendation, incidentally, does not mean that you should never rest or have a change from whatever you are doing from time to time.

RECOMMENDATION TEN. Don't be afraid to say: "I'm busy", if in fact you are busy at that moment. Even your best friends should not have a total monopoly of your time.

Something to Think About, Problems to Solve

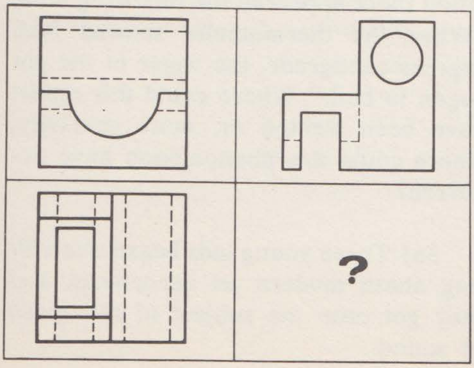
26) What is the difference between a bolt and a screw?

27) You have to draw a right angle (i.e. 90°), let's say for setting out a volley-ball or basket-ball pitch. You have no ruler or compasses, nor even a set square. All you do have is a piece of string and some wooden pegs.

To give you a bit of moral support and to assure that it can be done, I will tell you that the ancient Egyptians could do it, and they did not consider it to be a particularly difficult task.

Can you do it?

28) On this drawing you can see three projections of a single object: the views from the front, the side and the top. It is left to you to draw a three-dimensional picture of the object.



29) Study the square below for one minute only. Then cover the square, and try to write, on a separate piece of paper, as many of the words as you can from the square (without peeping).

If you can write down more than half the words, then you have a good memory.

30)

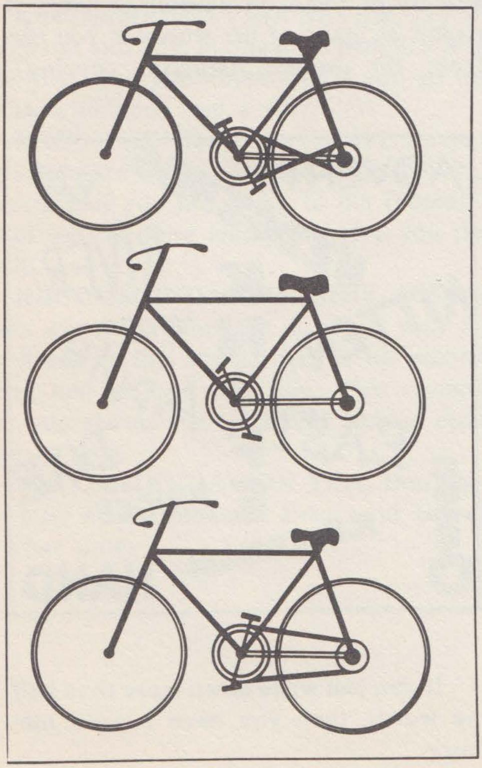
5 kg. △ 1 kg.

10kg. △ 1kg.

The above diagrams are, of course, correct: both 5 kg. and 10 kg. can balance 1 kg. It is all a question of the lengths of the various arms of the scales. If the longer arm is five times the length of the shorter, then 1 kg. (on the longer arm) will exactly balance 5 kg. OK?

So where did Archimedes go wrong when he said that he only needed the right place to attach a pivot to, and he would move the Earth?

31) Take a look at the drawings of the three bicycles below, and then say whether they will move and, if so, in what direction.



32) In an old wood-shed there was a window 50 cm. high and 50 cm. wide. The owner of the shed decided to make it into a summer-house. He asked a glazier to double the size of the window.

The glazier did as he was asked. The window became exactly twice the size of what it was before, but its height and width both remained at 50 cm. each.

How could this be?

33) Can you roll a barrel onto the back of a lorry without touching the barrel with your hands? This is not a trick question, nor is it a conjuring trick, because barrels should be rolled like this, without touching them with your hands. Why?

34) You have seen cranes in flight, of course, their wedge-shaped formation extraordinarily precise. How they achieve this co-ordination is still a secret which man has not yet uncovered, but can you say what the point of the wedge shape is?

35) In the report of a certain expedition there appeared the following note: "When the thermometer showed 86.6 degrees centigrade, the water in the pot began to boil." Where could this report have been written or, more precisely, where could this phenomenon have occurred?

36) Three young lads began quarrelling about modern jet aeroplanes, and they got onto the subject of the speed of sound.

Kolya said that sound travels through air at 319 metres per second.

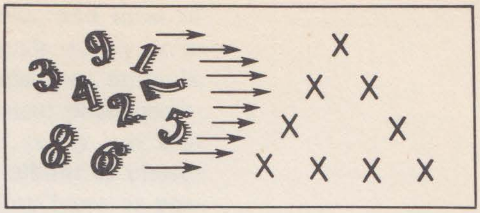
Vitya said he was wrong, it wasn't 319, it was 332!

"Neither of you knows anything," said Oleg. "The speed of sound travelling through air is 343 metres per second. And that's a fact!"

Which of the lads was correct?

37) $48 \times 159 = 7{,}632$. This multiplication has been worked out quite correctly, there's no trick. But can you say what is special about this multiplication?

38) In the box below the idea is to put one of the nine positive digits on each of the crosses to make the sum of the digits on each side of the triangle equal twenty. That is the first part of the question. The second part is to rearrange the digits to make the sum of each side of the triangle equal seventeen.



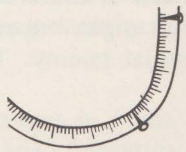
39) You have a photograph in your hand. It is a picture of you in front of your house, standing by a tree, or maybe standing at the bottom of a cliff. From the photograph, can you work out the height of your house, the tree or the cliff?

Some Useful Hints

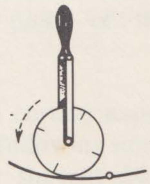
Engineers at all stages of their technical development will come across curves: the curve round the frame of a boat, the outline of an aeroplane's wing, part of the pattern of a home-made rucksack, or whatever.

But how would you draw a curve if you don't have a special curve-drawing instrument? And how would you measure the length of a curve?

One quite handy way of drawing a curve is to knock in some small nails along the line where you want the curve to be, and to bend a plastic or steel ruler round them; you can then draw round your ruler and you have your curve.



To measure curves there is a simple gadget you can make, using a circle of stiff cardboard, plastic or plywood with a diameter of 32 mm. You should fasten this circle to a wooden handle so that it revolves freely round its axis, and the gadget is ready. Only don't forget to make a mark on the edge of the circle, or better still — four marks, at equal intervals.



You can roll the wheel along any curve and for each revolution it will measure 100.48 mm., so that for all practical purposes you can call it 10 cm. And, accordingly, half a turn will be 5 cm., a quarter turn — 2.5 cm.

This gadget is very useful for unevenly curving lines, such as those on a map. If you know the scale of the map it is easy enough to find the distance in kilometres. With a scale of 1:200,000 (1 cm.= 2 km.), one turn will represent 20 km.; with 1:500,000 (1 cm.= 5 km.) one turn will be 50 km.; and with 1:1,000,000 (1 cm.= 10 km.) one turn will be 100 km., etc.

Many people nowadays own a camera, and most of all they like to take pictures of their friends, singly or in groups, or else they look for beautiful landscapes, animals, or various genre scenes. But very few amateur photographers take any interest in machines. Is it really not that interesting to make up, for instance, an album of photographs of every type (or, at least, as many types as possible) of machine, say, from a child's scooter to one of those gargantuan tip-up lorries used for building new roads? And if you make a note of the technical details of each machine photographed, you will have a most fascinating collection.

Making up an album like this can be quite useful, studying the pictures in it, considering the shapes of all the machines that surround you. And don't ignore the humble household machinery around you, maybe a sewing machine or a typewriter. If, for instance, you look at the development of the outline of the sewing machine over the last fifty years, you will learn a great deal about the general laws of technical aesthetics.

What do you know about the *scientific organisation of work*? Did you know that the people involved in this new and important field of human understanding have discovered many interesting facts? A logical lay-out of the tools on a work-bench (the same tools, just set out differently) can increase productivity one and a half times and reduce tiredness by one half. Even the colour of the walls and the equipment can have an effect on productivity.

Those are the facts; and the recommendation is — think about how to organise your work. Remember that a table lamp in the right place (to the left, and a little beyond the page you are reading), text-books and notebooks put in the correct order before you start, all the rulers, set squares, pens and pencils you will need, prepared and on your desk — this will all help you not only to save time, but also to do your work with fewer omissions and mistakes.

And then when you start constructing something, a proper organisation of your work takes on even more significance. At first, perhaps, you won't be able to manage

to work *scientifically*, but you should at least get as far as a *sensible* organisation of your work.

Everyone knows what a "rough copy" is; it is a preliminary sketch, calculation or the first draft of a text. But for some reason very many people think that a rough copy is a rough copy because it is supposed to be rough, and full of ink-blots, and crossings-out, and corrections. Some rough copies are written so "roughly" that even the writers of them cannot work them out later, and don't know which is the beginning, which the middle and which the end. A preliminary draft does not have to follow all the rules of calligraphy, but I would advise you to number all your points, or indicate in some other way which item comes first, which second, etc. This will help you later when you want to follow through your thoughts from beginning to end.

$$ax^2 + \frac{3}{4}ax + \frac{ax^2 - 2a}{a - x} : \frac{a + x}{ax^2 - 2a} : ax\text{... etc.}$$

$$1)\ \left(\frac{ax^2 - 2a}{a - x} \times \frac{ax^2 - 2a}{a + x}\right) : ax$$

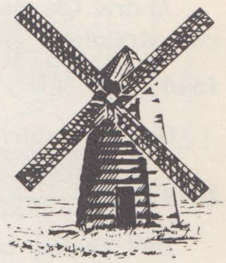
$$2)\ \frac{(ax^2 - 2a)^2}{(a^2 - x^2)\,ax}$$

$$3)\ \frac{4ax^2 + 3ax}{4} + \frac{(ax^2 - 2a)^2}{ax\,(a^2 - x^2)}\ \text{... etc.}$$

The algebraic lay-out in this example is quite conventional, and the rule it reflects applies to all "rough" copies.

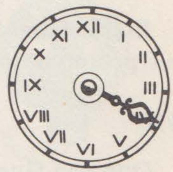
Dates on the Calendar

10th century AD



Windmills are being built in Western Europe. It is a curious fact that this child of human inventiveness has lasted a fantastically long time; even in our space-age twentieth century we may still find the slowly turning sails of a windmill. And the idea of using wind-power is not lost; people are still working on the development of effective wind motors.

12th century-13th century AD



The first mention of a compass in Europe.

The invention of a mechanical tower clock with one hand.

14th century

The invention of silk-throwing machines.

1450

The appearance of spectacles with lenses.

The first blast furnaces are built in Europe.

Johann Gutenberg invents movable type for printing books, and opens the first printing house in Mainz. People need books. Knowledge grows, experience accumulates and information becomes ever more extensive: life demands the means of preserving, spreading and communicating mankind's greatest treasure — knowledge.

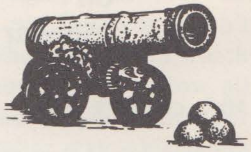
15th century

The first portable time-pieces with spring mechanisms are invented.

The first mention of a paper-mill in Russia.

1564

The first dated book is published in the Moscow printing house of Ivan Fyodorov and Pyotr Mstislavets.



1586

Andrei Chokhov casts the Tsar-Cannon for the Moscow Kremlin.

1610

Galileo Galilei invents the microscope.

1619

Dud Dudley takes out a patent on the manufacture of cast-iron using bituminous coal.

1645

Blaise Pascal builds the first adding machine, the distant prototype of the modern calculating machine.

1650

Otto von Guericke invents an air pump for experiments with the "Magdeburg Hemispheres".

1698

Thomas Savery builds a steam-operated machine for pumping water out of mine shafts.

Early 18th century

Denis Papin builds a steam boat.

1711

Thomas Newcomen builds a steam-atmosphere engine for mining pumps.

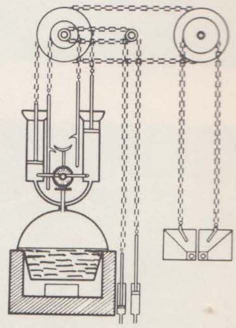
1718-29

Andrei Nartov, a Russian engineer, builds a series of duplicating lathes with mechanical carriages.

Middle 18th century

Interest increases in the phenomenon of natural electricity. Many experiments and a great deal of research are undertaken in this area.

1763



Ivan Polzunov, a Russian inventor and heat engineer, develops a project for a universal heat-engine.

1765

Ivan Polzunov builds a steam-atmosphere engine for factory use.

1760-70

The weaver James Hargreaves solves the problem of mechanised spinning.

1769

James Watt takes out a patent on a steam engine.
A steam carriage, built by Nicolas Cugnot, is tested on the streets of Paris.

1783

The Montgolfier brothers undertake the first flight in an air-balloon.

1784

James Watt takes out a patent on a double-action steam engine.

1797

Henry Maudslay builds a screw-cutting lathe with a variable lead screw. He also builds an automotive carriage lathe on a cast-iron mounting.

Early 19th century

Metal rolling mills begin to be used.

1802

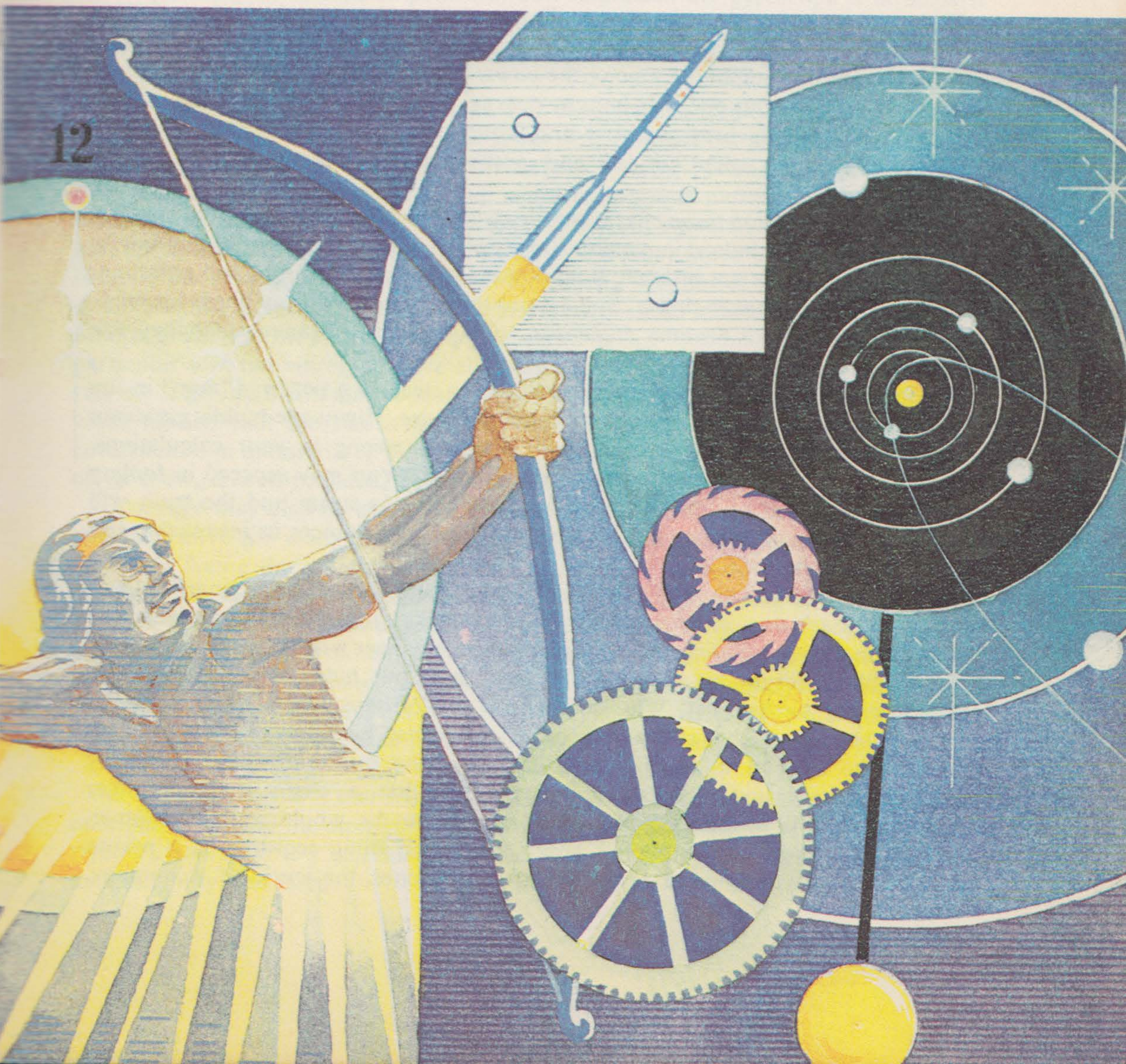
Academician Vassili Petrov, a physicist and one of the first Russian electrical engineers, builds the largest volt column of his time and makes observations of the electric arc.

Every engineer, and indeed every educated person, will be familiar with the name of James Clerk Maxwell, an outstanding physicist, founder of the theory of electromagnetism, and a man who continued the work begun by Michael Faraday.

Maxwell was born in 1831, and in April, 1846 in the Transactions of the Royal Society of Edinburgh there was a synopsis of his article on oval curves: James Clerk Maxwell was only just turned fourteen *when he wrote this very profound work.*

Incidentally, history tells us that Maxwell's article was read at a meeting of the Society by a certain J. D. Forbes, since in those days it was considered improper for a mere schoolboy to address the members of the Society directly. Nonetheless, Maxwell's article and the ideas expressed in it were received very well at the meeting.

4



A Few Particulars About an Engineer's Character

When you say, for example, that a pilot needs courage, you may often get the quick reply: "But doesn't a surgeon need courage as well?", or "Deep-sea divers, incidentally, are not numbered among the cowards of this world." True. Of course, it would be nice if everyone was honest, courageous, noble, persistent, inquisitive, kind, warm-hearted, devoted, attentive and thoughtful — in a word, perfect, rather than everyone being small-minded and petty. And there's really no arguing with that.

But I want to mention those characteristics without which, in my opinion, it would be very difficult, if not indeed impossible, for a person to be an engineer of any worth. A person's character is not in-born, it is subject to change, alteration and polishing, it adapts to the situations facing it. And I don't think it would do any harm for engineers, who have yet to become engineers, to find out in advance what they are lacking.

An engineer should be totally honest. You may deceive a person ("may" in the sense that it is possible), but you cannot deceive nature. If you are building a steam boiler or compressor, let's say, and something goes wrong in your calculations, there is no point in pretending that everything is OK. You may succeed in fooling all the technical control departments, but steam remains steam and the truth will out — when your unfortunate machine blows up and pronounces its inexorable and irrevocable sentence!

Besides which, you should also remember that nowadays an engineer seldom works alone. Each one, of course, does his own work, but this work is an indispensable brick in a large building. And just imagine an engineer who solves his own individual problem, forges his own link in the chain, but hides some doubt, some defect or error on his part. Why does he do it? Perhaps from a false sense of shame in the eyes of his colleagues; perhaps because he fears to lose the trust of those who happen to have trusted him. But the question why is probably not all that important. Far more important is that a chain is no stronger than its weakest link, that a faulty brick will cause the whole wall to collapse. That is why honesty of the highest order is the first thing required of a person who intends to devote himself to the world of machines, the world of technology,

the world of complex systems: because systems are what it is all about.

An engineer should be inquisitive. If you get on with your work, as it were, blinkered, taking no notice of what is going on around you then, however hard you may try, you and your work will always be bringing up the rear. And Lord help you if you scorn the work of others, if you begin to think to yourself: "What can those textile workers or sausage manufacturers teach us — us, the builders of super-modern technical miracles!" A friend of mine, a highly respected aviation engineer, is constantly looking in toy shops: he is firmly of the opinion that things like the construction of a mechanical acrobat or a toy pistol that shoots arrows with rubber suckers on the end can act as a stimulus for the most interesting ideas. I may mention, by the way, that the theory of the gyroscope began from studying a child's spinning top. And I probably don't need to point out how important the gyroscope is in modern technology: suffice it to say that all auto-pilots are built using this principle, and many of an aeroplane's other instruments too.

Good ideas are always welcome.

An engineer should be courageous. For example, the tradition has built up over many years (and, correspondingly, a great deal of practical and theoretical experience has also built up) of lifting heavy weights by means of various types of cranes. And then a new solution is proposed: someone suggests putting high metal structures in place using helicopters. Everything is carefully calculated down to the last detail, the strength of the cable is tested three or even four times, and all the manoeuvrings of the helicopter are thought through taking account of all the possible turns of the wind. It seems that everything is in order. But still, it takes courage to give the final command to lift a steel roof, a girder or a bridge section. It takes courage of a particular sort: not merely to wave all doubts aside and loudly pronounce: "OK, let's risk it!" It takes a brave man to march against tradition, it takes a strong man to convince himself that the risk is justified, that his engineering responsibility for the construction in question, for the fate of the helicopter, and even perhaps for the lives of its crew, is well-founded, justified, necessary and expedient.

Courage may also be expressed in rather more mundane situations. Rivets, for example, have for many years been considered by aviation experts to be the best means of fixing the individual elements of a whole range of constructions.

And then some bright engineer, call him X, starts casting doubt on this traditional opinion. His argument runs as follows: to rivet a whole aeroplane wing, for instance, we need to drill tens of thousands of holes first; and that means a great deal of work; besides, each hole drilled means weakening the material from which the wing is made; but that is not all; each rivet is not all that heavy, but if we multiply this insignificant weight by thousands or tens of thousands then we arrive at a very appreciable total.

Let's say this is all so, but what can be done about it?

It is the opinion of X that rivetted joints can be replaced by welded joints. Experience shows us that the strength of a joint is not lessened when welded rather than rivetted, but rather it is increased. And the amount of work involved is reduced, and the reliability increased.

Pafnuti Lvovich Chebyshev, the outstanding mathematician of his time, a member of seven academies and innumerable scientific societies, staggered the whole scientific world with his paper "On Dress-making". Presenting this study at a Paris conference in 1878, he produced five small cardboard patterns. With a smile he showed a ball, closely covered with several pieces of material cut out to his design. This well-fitting cover demonstrated quite clearly that the patterns used in practice for dressing spheres and other rounded objects were far more complicated than the design which he himself was proposing.

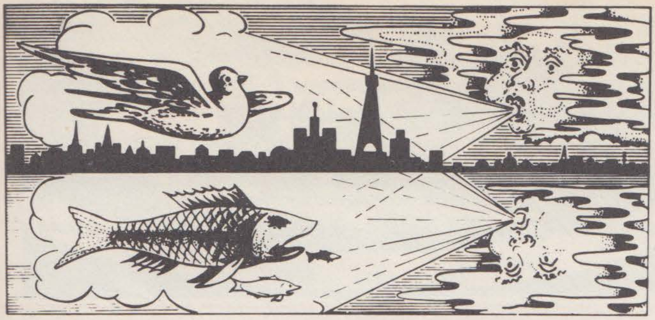
And X is told: "Alright, your conclusions sound quite convincing. Try out your theory in practice."

And that is the moment when a man has to decide. Just think what it means! He has to go against years and years of practice, has to turn his hand against authoritative opinion, and set himself and his idea against a long-standing habit. But what if there is a mistake somewhere, an error, or something goes wrong by chance? He may be a very talented engineer, but without simple human courage he will not take the last step, not for anything in the world.

An engineer should not be indifferent to the world of science. You may be a thousand times a practitioner: a manager of the works on an ordinary building site, a departmental manager in a rank and file factory, or even a humble mechanic in a repair shop: whatever you are, science, its development and problems should concern and fascinate you. The knowledge that you picked up in your college studies may last you for five years, or maybe more. If you do a bit of reading, or attend lectures to get yourself better qualified, you may last out ten years. But "last out" is the operative expression. To stride out, as it were, to breathe deeply in your chosen work, and to be indispensable in it, you need to keep in step with science.

Even if he passed his exams with flying colours fifteen or twenty years ago, a mechanical engineer would have had only the most basic notions of chemistry — if, of course, his exams were not specifically directed towards chemical engineering. And now he has a job. He has got on well, let's say, in a car-assembly plant, he is in charge of a whole department, gaining experience all the time, getting used to giving orders and taking decisions, and finding solutions to any problems which may arise.

But one day the assembly department begins to get parts made of new materials: perhaps bushes made from a metal-substitute, elasticated film, or plastic panels. How is he to deal with the products of modern chemistry? Can he heat the bushes and, if so, how much? How can he fix the film? Can he use glue, and what sort? How is he to stop the plastic panels from going out of shape, warping or even falling apart altogether? The questions just grow and grow, like mushrooms after a summer rain. And willy-nilly, the mechanical engineer is forced to delve into the labyrinth of chemistry: an ordinary car nowadays has more than five hundred plastic parts!



Not so very long ago scientists discovered a most curious fact: an object in a vacuum chamber remains in near-perfect condition after the end of its expected useful life. It neither falls apart nor becomes unserviceable. Aluminium, for instance, is between four and seven times harder in a vacuum. Why is this? Metal "fatigue" is usually caused by microscopic cracks. In the Earth's atmosphere the walls of the new crack are immediately covered by a layer of oxidised metal and adsorbed gasses. In a milliardth part of a second the coating becomes one molecule thick. In the rarefied atmosphere of a vacuum chamber this process takes three hours. But ... in that time the walls of the crack manage to close, "heal over". The metal heals itself! This was proved by science. And of course, those involved in space technology should be aware of things like this. This knowledge allows them to build lighter, finer, more economical and, at the same time, more reliable craft.

Until very recently glass wool, glass fibre and glass thread were the rarest of materials, laboratory rather than industrial materials.

But time has passed, and glass-reinforced plastic has begun to be used to make ships, car bodies, machine beds, etc. The makers of brake parachutes for supersonic aeroplanes and landing parachutes for rockets also include this sort of material in their designs. And nowadays brake parachutes are made from a cloth of interwoven metal and glass-fibre threads. Each square metre of this cloth uses eighteen kilometres of wire, and the cloth can withstand temperatures of up to eight hundred degrees centigrade.

You can find as many examples as you like of the very wide use of science in the field of technology. Pafnuti Chebyshev, the outstanding Russian mathematician of the nineteenth century, used to say that the harnessing together of theory and practice gave the most beneficial results and that practice was not the only winner: "Practice influences the development of science itself, it opens up new objects of research, and new aspects of even the best-known objects."

I realise that it is practically impossible to exhaust this topic, but I would like to give just one more interesting example of interaction.

Aerodynamics is a highly respected science, and it has a well-defined area of problems and concerns. The major, as it were, consumers of the science of aerody-

In the autumn of 1912 the ocean liner Olympic *was sailing in the open sea; the battle-cruiser* Hawke *was following a parallel course. Suddenly the* Hawke *changed direction and, out of control, began to head straight for the ocean liner. The two ships collided.*

It was decided by the marine tribunal that the guilty party was the captain of the Olympic *for having taken no measures to let the* Hawke *pass.*

If the tribunal had taken into account the theorem postulated by Daniel Bernoulli as early as 1726, the basic law of hydrodynamics, then no one would have charged the Olympic's *captain with inefficiency.*

namics are the builders of aeroplanes, gliders, helicopters, aero-engines, hydroplanes, aero-sleighs and the like. The builders of aerial towers sometimes turn to aerodynamic specialists for help: they may need to know what effect gusting and gale-force winds will have on the construction which they propose to build. Car manufacturers also resort to the specialist knowledge of aerodynamics: they may want to test the model of a new racing car in a wind-tunnel, to determine the coefficient of head resistance of models No. 1 and No. 2 at speeds close to those of an aeroplane. Aerodynamic experts never refuse to help out in such cases. But these are only side-issues for them, supplementary, "extra-mural" problems.

But then one day some ship-builders come along with a problem which is not so incidental or ancillary: their question is quite fundamental and touches upon a totally new principle. How will wings react when surrounded not by air, but by water?

Careful study, calculations and many bold experiments go into a completely new area of ship-building, and we see the birth of a new means of transport, hydrofoils, the children of a union between ship-building engineers and scientists in the field of aerodynamics.

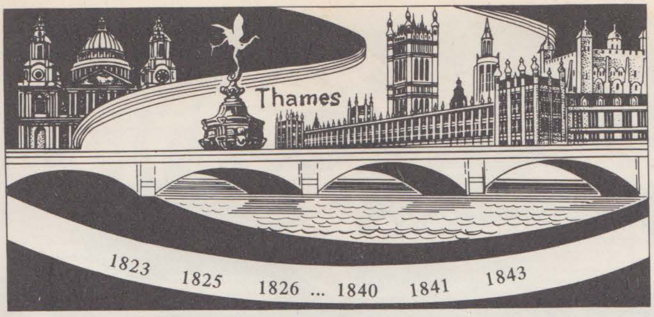
As I say, you can find as many examples as you like of the advantages of being aware of what is going on in science.

An engineer should be patient. Once, while visiting an engineering institute, I was witness to the building of a model for a huge dam. Very much scaled-down concrete blocks were being put together with the greatest care. Each component of the structure was numbered, and each link was registered in a special book. The people involved were crawling around the floor on all fours from morning till night.

"But after all," I said to the leader of the group, "it's only a model. Why are you taking so much trouble? Whatever comes, your model won't have to last for centuries!"

"That's just it: we're not building it to last for centuries. That's why we have to test, evaluate and foresee everything. We're putting it together for the ninth time! We're in a hurry. The real dam, when it's built, will have to last for centuries, and it will be too late then to experiment."

The engineers were pressed, very pressed for time: they needed tested facts,



figures carved not from dull formulae but from a living, raging, albeit scaled-down, torrent. How difficult it must have been for them — to be in a hurry, and yet not to rush things, not to make mistakes, to vary the way the concrete blocks were laid again and again, to alter the design of the sluice gates, to change the spillways around...

That was more than twenty years ago. The dam is not a toy one now, it is real and in full operation: it is unlikely that anyone today remembers the patience of the designing team. Patience was their professional duty, and a trait of their characters at the same time. It was nothing unusual, it was, if you like, the order of the day.

Anyone involved in technology needs patience, no matter what his job is — whether it is building dams to last for centuries, or just repairing ordinary, everyday mechanisms.

Marc Isambard Brunel is quoted in the old *Edinburgh Encyclopaedia* as saying that he got the idea for building a tunnel under the Thames from the Teredo, a small worm covered in cylindrical plates which could eat even the hardest wood. It was this little wood-worm that "set things in motion".

Brunel proposed his tunnel in 1823. And for this unprecedented undertaking it needed an unprecedented machine, to be built by a bold engineer.

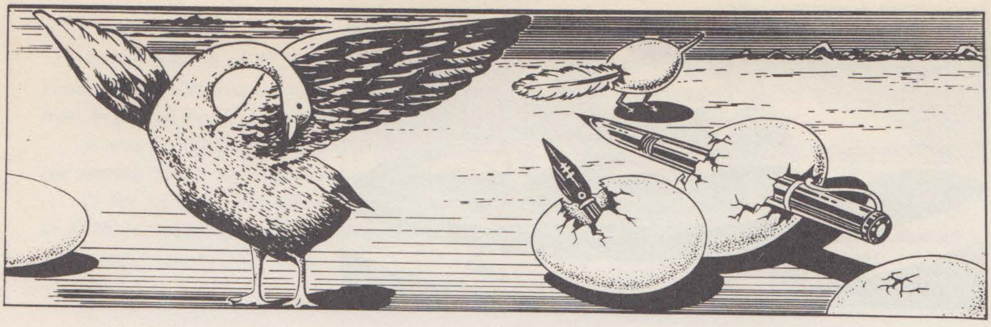
And now let us look at the chronology of events.

The project was proposed in 1823. There were then two years of arguments and discussion: was Brunel's idea feasible, or was it just another utopia?

1825, and the work began.

On New Year's Day, 1826, the vertical shaft was completed, and the tunnelling machine was ready to start work.

On the 14th of September, 1826, the tunnel was flooded. The debris from the flood was cleared away, and there had been no casualties. The work continued. In October, 1826, the tunnel was flooded again, there were no casualties, the debris was cleared away again and the work continued. The next flooding was on the 18th of May, 1827: there were no casualties, and the last to leave the flooded area was Brunel himself. When the tunnel was flooded again on the 18th of August, 1828, six people were killed.



The company then ran out of money and work was halted. The next seven years were spent in proving that the idea was actually feasible, and in finding the means to continue the work. At last, workers went down into the tunnel once more. Things moved very slowly: three floodings in a row represented three terrible blows for the builders. The last of these three floodings was in August, 1837. Brunel continued to improve his machine. Brunel would not give in.

November, 1837, and the river broke into the tunnel yet again. One man died, the debris was cleared and the work continued.

In March, 1838, there was another flooding: no casualties, the debris was cleared and the work continued.

April, 1840, and there was a landslip in the tunnel.

On the 13th of April, 1841, the tunnel reached the far side of the river.

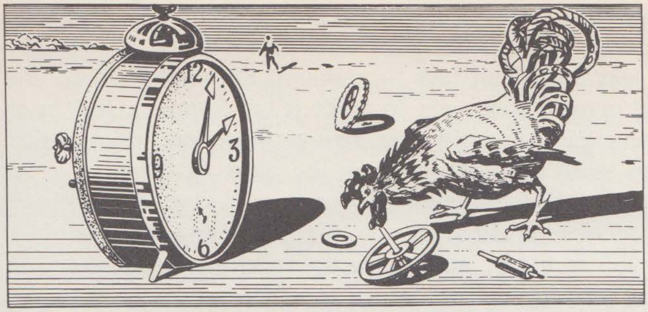
Traffic began to use the tunnel on the 25th of March, 1843.

That is engineering patience for you, a patience without which it would have been impossible to endure what was endured by the men who built the first tunnel under the Thames.

And that is how it must be — in all matters.

Many, many years ago people wrote with goose quills. At the beginning of the nineteenth century Russia alone sold between twenty and thirty million goose quills to England alone (one goose, incidentally, provided between ten and twenty quills suitable for writing). An ordinary goose quill was expensive, and soon wore out because it needed constant sharpening. In 1780 Samuel Harrison invented the steel nib: but it took nearly a hundred years of patient improvements, and of research into the best means of producing them, for steel nibs to oust goose quills entirely.

With steel-nibbed pens in their hands people immediately noticed the major defect of these instruments: that the pen existed separately from the ink-pot (it is characteristic that while people wrote with goose quills they did not notice this particular imperfection). The more widely steel-nibbed pens were used, the more persistently people sought a means to combine the pen and the ink-pot. In the middle of the last century the first fountain pens appeared; another fifty or sixty years of



patient effort and the fountain pen was "perfected", it was able to rival the ordinary pen and ink-pot, it became reliable and durable, and it was reasonably priced.

Patience, patience, and many, many more times patience — this is what has driven technology forward from one achievement to another.

Patience. I would very much recommend everyone who intends to devote themselves to technology to develop in themselves this most valuable engineering quality. "How?"— you may ask. There are many ways of doing it: some are quite simple, and some are more complex. When I was about seven or eight years old, my father was always giving me knots to undo. Where he got all these matted and tangled messes of ill-assorted string from, I'll never know. And, of course, I was strictly forbidden to use scissors, razor blades or knives. I cursed the string, I cursed the people who invented the very concept of string, but most of all I cursed the people who had made the tangled messes: I got mad, and nearly went up the wall. That was in the beginning. But then I became a dab hand at it and could undo any mess in under fifteen minutes.

And there are many games for training a person's patience, from the simple spillikins or barrel-of-monkeys, to something as complicated as the following game: a tin can is placed five paces away from a mark on the ground ("the throwing line"), and each person playing has ten small stones. The idea is for each player in turn to throw his stones into the can, and the winner is the one who puts all ten in in one go. And you can keep score if you want. This game, incidentally, will train not only your patience, but also your ability to judge distances on sight. If the game becomes too easy, it is always possible to "toughen it up": you can set the tin can further away, or take it away altogether and replace it with a circle drawn on the ground (it is far more difficult to land on a flat circle than in a container).

But the best way of training your patience, in my opinion, is to work with the mechanisms of watches and clocks. If you are able to take apart and, it goes without saying, to reassemble even the most simple of alarm-clocks, then you can consider that you have passed a test, perhaps not yet as a master craftsman, but at least as a "master of patience".

And, by the way, please don't ignore watches and clocks, because clocks were the first machines which mankind used for practical purposes, and it was on the

basis of their mechanisms that the production of uniform motion was developed.

An engineer should be orderly. Without fail! When the prototype of the TU-104 aeroplane was being built, it was a difficult task to gather it all together from the twenty thousand drawings and plans which went to make it up. Suppose, just for a moment, that these plans were executed any old how, then you can very well imagine that it would be impossible to build the aeroplane on the basis of them.

For example, the TU-104 takes thirty kilometres of various wiring. If this wiring were to be installed in a disorderly way, although you might be using the best plans in the world, there is no way you would be able to fly the resulting aeroplane. The thirty-kilometre web, stretched out just anyhow, joined together carelessly and soldered in a slipshod manner, would be incapable of disentanglement not just by the designer — the Lord God himself wouldn't be able to find and correct even the smallest fault in it.

I remember talking once to a designer working in a factory which built small-engined cars; as we talked he twirled a finely, dare I say — artistically, sharpened pencil in his thin, dry fingers. I made a comment about the time wasted on such a "cosmetic" operation. The designer looked at me and, clearly disapproving of my remark, without a shadow of a smile said:

"In a certain sense, if you like, an engineer begins with the sharpening of a pencil."

Later I learnt that in this man's twenty-five years of designing no one had ever had occasion to return a drawing to him for correction. He was often criticised for unnecessary pedantism, but people were happy to learn from his example and to copy him.

An engineer should have a good working knowledge of the human anatomy. Before taking this topic further and illustrating it with examples, let me ask you a very simple question: how many degrees of movement does your arm have? Have I stumped you? I wouldn't be surprised. But machines are built for people; and therefore anyone who designs, builds of improves machines must always take proper account of the abilities of the people who are expected to operate the machines in question.

I remember one particular engineering error in this line: once, around the time of the Second World War, a small constructional amendment was to be made to a Soviet aircraft — the lever raising and lowering the undercarriage was moved from the main instrument panel to the panel at the pilot's side, and it was put next to the outwardly very similar lever for operating the wing flaps. The designers' idea was quite simple: the two levers, being so close together, would reduce the amount of movement required of the pilot, and would allow him to move his hand more quickly from one to the other. It is very possible that there were other reasons as well — for instance, a reduction in the number of air-pressure cables in the aeroplane's design. Everything seemed to have been done properly. But ... the aeroplane would come into land, but instead of withdrawing the wing flaps, the pilot pulled the wrong lever and withdrew the undercarriage. Whop! The aeroplane would land on its belly, the

propeller blades got bent, the fuselage was scratched and the wing flaps were put out of shape.

So what was wrong? The engineers had not taken account of one of the purely human attributes of their pilots — habit. The pilots were accustomed to finding the levers by touch, not looking at the levers themselves: the undercarriage lever being habitually on the instrument panel, and the wing-flap lever — on the side panel. It may well be, from the technical point of view, that the amendment was in order and expedient, but by ignoring the psychological peculiarities of human nature the designers brought about a number of unexpected and extremely unfortunate accidents. In the event, the designers had to shelve their "improvement".

Not so long ago I read what was at first glance an amusing story. A large group of English optical engineers, electrical engineers, electricians and other specialists had spent a lot of time developing a super-precision aeroplane gun sight. The designers had had to overcome the most improbable difficulties, both of a scientific and of a purely engineering nature. Finally, this wonder sight was built, set up, tested on the ground, and ceremoniously installed in the relevant aircraft. Everyone was certain that the work had been done splendidly and that the attendant representative of the Royal Air Force would give it a glowing report.

The test pilot took off to try out the device in the air, and the engineers waited on the ground. I know what it is like to wait for the return of a test pilot: you put on an indifferent appearance, you may crack a few jokes or smoke a cigarette — but at a time like that everyone's insides are trembling with impatience.

At last the aeroplane landed and rolled to a halt. The pilot climbed slowly from the cockpit. He looked closely at everyone gathered there, and said:

"You have built a wonderful piece of equipment, gentlemen, but you will have to put a bit of a finishing touch to it — by providing me with a third hand."

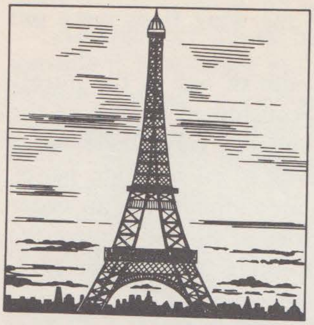
The instrument was designed to be operated two-handed, and the designers simply forgot that to fly the 'plane the pilot would need at least one hand!

I once came across a motor car which could only be driven in the daytime: as soon as darkness approached the windscreen would reflect the steering wheel, the dash-board, the driver's own face and the face of his front-seat passenger. In short, the driver could see everything except the road.

And I have already mentioned the television designers' error in putting the adjusting knobs on the back of the television and thus preventing a person from seeing immediately the results of his efforts to adjust the picture.

The conclusion is obvious: an engineer should always know what a person is like, understand his psychology, take account of his physical capabilities and correctly allow for such "trifles" as the length of a person's leg, for instance, or the maximum force which a human hand can generate, or the speed of his optical reaction. As Protagoras, the pupil of Democritus, wrote: Man is the measure of all things.

And the question about the degrees of movement in a person's arm? Well, there are twenty-seven! The shoulder has three degrees, the elbow — one, the wrist —



three, and the thumb and each finger has four. Which adds up to: $3 + 1 + 3 + (4 \times 5) = 27$.

If only an engineer could build a machine with such a high degree of manoeuvrability as the human arm!

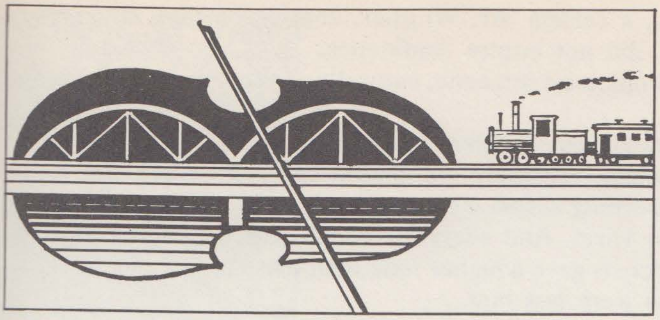
An engineer should have a sense of the beautiful. It is not all that important what your preference is for: music, painting, sculpture, or maybe you just cannot remain indifferent to the beauties of nature. What is important is that your soul should tremble, sing and take to the wing under the influence of harmonious sounds, the perfect proportions of a naked body, or the unique glow of the Northern Lights. And no one should be surprised that I mention beauty in relation to people involved in technology. Fashions may come and go, fashions may disappear and reappear, but the Eiffel Tower will never be out of fashion because it is beautiful and perfect, because it is beauty itself, embodied in metal tracery.

The bridge, built by the Soviet Academician Yevgeni Oskarovich Paton to span the River Dnieper with unimaginable grace, will also never be out of fashion. Perhaps in time someone will start to criticise the railings or perhaps will think that the lamp-posts are out of date, but the amazing precision of its unbroken welded lines, which seem not to hang, but rather to fly, over the Dnieper's waters, can never age. This is an absolute value, and not just in engineering terms: it is a spiritual and an aesthetic value as well.

I am certain that the Tupolev jet air-liners of the 1950s will not seem archaic to even our most distant descendants. The perfect flow of their lines and the fluency of their swept-back wings are not just an engineering achievement, they are an artistic revelation.

Of course, not every engineer can hope to emulate the great Leonardo da Vinci and be both an outstanding engineer and an outstanding artist. But it is absolutely essential for an engineer to have a sense of beauty.

Dmitri Konstantinovich Chernov, the great Russian metallurgist of the late nineteenth and early twentieth centuries, spent much of his spare time making superb violins, and even specialists were not always able to tell the difference between his work and the work of the old Italian masters.



I was visiting Oleg Konstantinovich Antonov, the aviation engineer (remember, the man I have already mentioned, complaining about archaic and uneconomical means of reloading a crop-spraying aircraft?), and in his flat I saw a wonderful painting; it showed an angry sky before a storm, deep blue, violet and black. The feeling of space and the battle between the forces of the blind elements... But it is hopeless to try and describe the picture in words. Believe me, it was a marvellous picture, and I asked my host:

"Who painted this picture, Oleg Konstantinovich?"

"Oh, that? I do some painting in my spare time, I don't paint much, of course, and I'm only an amateur, but I love painting, I have always loved it."

And now I would like you to read the two paragraphs that follow, read them slowly and try to picture the scenes:

"The sky was heavy with storm-clouds, and to the west their dark masses blotted out the evening sun. Its fiery rays shot out from beneath them and scattered short, red flashes across the steppe lands...

The trees seemed to be alive and whispering to each other. Their upper branches were far away in the deep-blue depths of the sky, where the stars twinkled brightly, as though lost among the leaves."

Can you feel the beauty?

These paragraphs were written by one of Russia's best railway engineers, Nikolai Georgievich Garin-Mikhailovsky; he was the author of a number of books, including *Tema's Childhood, Students,* and *The Engineers*. He was an outstanding writer and an outstanding man.

An engineer should have imagination. By this I don't mean a person's ability to day-dream, but rather his talent for finding solutions along untrodden paths.

One example of brilliant engineering imagination:

Dmitri Ivanovich Zhuravsky, an outstanding bridge-builder of the early nineteenth century, established that the tension bars and struts near the centre of a bridge span take less strain than those placed close to the bridge supports. On the basis of this discovery Zhuravsky reasonably decided that the diameters of the central bars and struts could be reduced.

An American consultant, a certain Mr. Whistler, considered that Zhuravsky's conclusion, to put it mildly, did not inspire confidence.

Thus there was a clash of opinions: someone, naturally, was correct, and someone was wrong.

While the matter was discussed, debated and argued about, Zhuravsky built a model of a small girder bridge, replacing the tension bars with wires of a single thickness. He spread weights evenly across the model bridge and, taking an ordinary violin bow, drew it over the wires. And everyone could hear for themselves that the wires near the bridge supports gave a higher tone than those in the middle: it followed that the central wires were less taut.

There was nothing left for Whistler to do but to admit that Zhuravsky's conclusion could be fully relied upon.

And a fact from a later period:

Everyone knows that one of the most inflammable materials was, and still is, high-grade petrol. It is also no secret that such petrol is used for piston-engined aeroplanes and is carried in tanks either in the fuselage or in the wings. These tanks were, for a very long time, the most vulnerable part of military aircraft: it only needed a bullet to make a small hole in one of these tanks and the petrol would drain away — at best — but if it was an incendiary bullet the petrol would burst into flames and cause an explosion.

It was thus a problem of life and death to make the tanks safe from holing and from fire. The first idea was to protect them with armour-plating, which of course was quite reliable, but inevitably added to the aircraft's weight. And in aviation, as you will be aware, the primary objective has always been to reduce weight by every gramme possible. So the leading lights in the aviation field continued to rack their brains over this particular safety problem.

And they found an answer. They rejected armour-plating and, instead, covered the tanks with a protective layer of untreated rubber. The covering had a remarkable effect: although it was quite easy to make a hole through it, it would seal up the hole of its own accord. And that was the solution to the first half of the problem: the petrol no longer poured out of holed tanks.

But there was still the problem of fire and explosions. On this point the engineers knew that the most inflammable element was not the petrol itself — the liquid — but rather petrol vapour. It had been observed a long time earlier that full tanks practically never caught fire, whereas half-empty tanks would explode like gun-powder.

They seemed to be caught in a vicious circle: while the fuel was still intact the chances of it catching fire were quite small, but once the fuel level began to fall — then let everyone beware! And there was no way that the petrol level could not fall...

One line of thought, however, went as follows: it is not the petrol that burns, it is the petrol vapours. And what are vapours? Gas. Precisely! But there are many gasses which do not burn. There are inert gasses which are completely incombustible and, moreover, which are actually capable of dousing flames.

This, of course, was not a discovery, nor an answer to the problem, it was merely the dawning of an engineering idea. The answer itself came somewhat later. The aeroplane's engine produced incombustible exhaust fumes which could be cooled and purified, and then pumped into the fuel tanks. As the fuel level dropped, more and more of the inert gas could be forced in so that there would simply be no room for petrol vapours. The vulnerability of military aircraft immediately became less of a problem.

And these two bright engineering solutions unexpectedly led to a third.

The engineers who were studying the damage done in aerial combat to the rubber-protected fuel tanks came to the conclusion that ten, or even twenty, small holes would disappear without trace in the layer of rubber. Thus the rubber, which had initially been added as an auxiliary measure, had turned out to be more important than the metal. Once the engineers were convinced of this they made their third decision: to do away with the metal tanks altogether and to replace them with sacks made of a rubber-based material. This was a brilliant solution to the problem: it allowed the "tanks" to be squeezed into all the corners of the wing spaces where it would have been unthinkable to try and put ordinary tanks. The sacks would be folded up and put into the relevant sections of the wings by hand and then, by filling them with compressed air, they would fill out into all the available spaces. Thus, without increasing the size of the aircraft, there was a marked increase in its tactical capabilities, its flight duration and its radius of operation. Moreover, the "better" and more accessible areas of the aircraft were freed for installing extra guns or ammunition storage spaces.

People's technical wit arose long before the invention of aeroplanes, railways and, what's more, long before engineering degrees and diplomas. And perhaps all technical progress is born of the ability to find imaginative solutions.

A long time ago the Pomors, the people living along Russia's northern coastline, made their boats out of whole tree-trunks, hollowing them out using either axes or fire. But the strange thing was that these "dug-outs" were two or three times wider than the broadest of trees available. Some sort of witchcraft, the finished product being bigger than the raw material!

There was once a well-known machine workshop in London, run by a man called Joseph Bramah. Incidentally, one man who worked for some time in this workshop was Henry Maudslay, whose name you will come across again in this book.

Bramah specialised in making security locks, and his work was in high demand. To demonstrate the excellence of his craft he put one of his locks on general display and offered a prize of two hundred pounds sterling, to anyone who could open it.

The lock lay unopened ... for seventy years! It was finally opened by an American in 1851.

But the cunning was in the technology. The Pomors would choose a broad, healthy aspen or lime and, before chopping it down, would split it from top to bottom and drive wedges into the crack. This was usually done in the spring. The wedges would be driven in deeper every three days. The tree would continue to grow and, because of the wedges, it would also broaden out. Bigger and bigger wedges were driven in, and later were replaced with wooden "spreader" bars: in short, the future boat was formed in the living trunk. It took five years to "cultivate" a boat, whereupon it would be cut down, worked to the right shape, and launched.

The most miraculous, and indeed the most ordinary, wheels are set in motion by the will of man. Which is why the character of the person who decides to make engineering his life is far from unimportant.

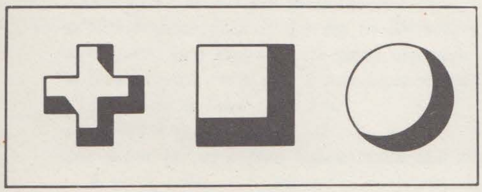
Something to Think About, Problems to Solve

40) Yet another table for you to consider. You have exactly one minute to study it:

$\dots \times 1 = 3$	$\dots - 4 = 3$	$\dots \times 7 = 3$
$\dots \times 2 = 3$	$\dots \times 5 = 3$	$\dots + 8 = 3$
$\dots + 3 = 3$	$\dots : 6 = 3$	$\dots - 9 = 3$

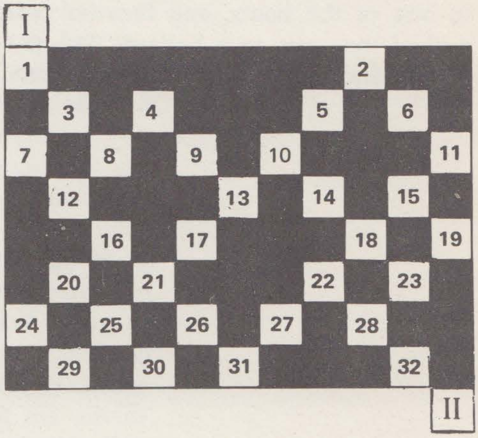
And now can you quickly put the right numbers on the dotted lines, so that all the answers are correct?

41) Is it possible to make a universal plug to fit in all three holes shown in the drawing below? Can you draw such a plug, if — of course — it can be made?



42) Trace the route from the square marked "I" to the square marked "II", passing through each of the white squares once only.

And write down the route in numerical order.



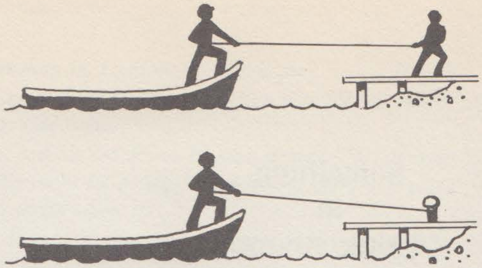
43) A few lines from a travel diary:

"We have been afloat for three days now. To our left there unfolds a picture of steep, precipitous banks; these are sometimes bare, sometimes covered in dense forest. To our right stretches a panorama of endless fields, the bright green steppe, then cultivated soil again..."

We know that the writer of the diary was travelling along the River Volga, but can you say whether he was sailing from the town of Gorky in the north to Astrakhan in the south, or vice versa?

44) A raft is floating on a river, floating at the mercy — as it were — of the waves and the current.

Question: is the speed of the raft equal to, less than, or greater than that of the current? Do not rush with your answer, have a think about the situation first.



45) Two identical fishing boats are approaching the shore. A man at the water's edge throws a rope to a fisherman in one of the boats, and ties the other end of the rope to a bollard. The man on the shore helps the other fisherman himself. All three men, the two fishermen and the man on the shore, apply equal effort to their tasks.

The question is: which boat reaches the shore first?

Some Useful Hints

What can the smallest coin of the realm be used for? In the Soviet Union a one-kopeck coin will buy you a glass of fizzy water, a box of matches, or a pencil eraser. OK? OK. But a one-kopeck coin, as indeed any other coin, has a number of particular features — a strict diameter and a strict weight: and therefore it can be very useful for various measuring and weighing purposes.

I can foresee the comment: "What's the use of all your suggestions about using matches, fingers, and now coins, to measure things with, when we have rulers to do all the measuring we want?!" I quite agree, it is easier using a ruler to measure things, but you have, of course, learnt to use a ruler long ago, and without my advice.

To give examples of measurements, using Soviet coins (but note that every country will have its own standard coin diameters and weights):

one kopeck is 1.5 cm in diameter;
a five-kopeck coin is 2.5 cm in diameter;
therefore: two one-kopeck coins measure 3 cm across;
a five-kopeck coin and a one-kopeck coin will give you a total of 4 cm;
two five-kopeck coins — 5 cm;
the diameter of a five-kopeck coin less the diameter of a one-kopeck coin — 1 cm;
a two-kopeck coin is 1.8 cm in diameter;
a three-kopeck coin — 2.2 cm.

And examples of the weights of coins (which, in the Soviet Union, are very easy to remember):

one-kopeck — 1 g;
two-kopecks — 2 g;
three-kopecks — 3 g;
five-kopecks — 5 g.

If you like making things in your spare time, then you will certainly have to use a drill ever so often: and whether it is manual or electric, you will often come across minor inconveniences, especially if you are drilling small holes in small objects. So why don't you build a gadget to turn your drill into a portable drilling stand?

By the way, with a bit of native wit this stand could easily be used as a small-scale lathe.

The word *instrument* has a very wide range of meanings. It can be a tool for work, with which you carry out certain specific operations (e.g. a hammer, a screwdriver, a drill, a chisel, a pair of pliers, and so on), or it can be a measuring and marking device (e.g. a ruler, a set square, a surface gauge, a calliper square, and so on).

And of course you should never use a calliper square for knocking nails in, or undo screws with a steel ruler, or try to bend a wire using a set square. Measuring instruments require very careful and considerate treatment, otherwise you will never produce anything that is precise, accurate and, so to speak, spot-on.

It is best not to keep measuring instruments in your tool drawer at all, but to have them in their own special covers and in a place apart from your work tools.

We all come across a variety of problems to solve — some more complicated, some less complicated; some intricate, some quite straightforward. Sometimes you will find the answer at once, and sometimes you will never find it, no matter how hard you look. And almost every answer needs to be tested.

Testing an answer can take many different forms, depending mostly on the nature of the problem. I would like to remind you here of one, very reliable, way of testing your answer, a way that is often forgotten.

When you write down, let's say, 100 km/hr, what does it mean? 100 is a quantity, and km/hr is a measure of quantity, in this case — speed. OK? When you perform an operation on a quantity, you automatically perform an operation on its measure. So, after finding your answer, first of all check your unit of measurement and if, for example, you have arrived at the length of

the path through the point *A* being equal to something in m/sec^2, then (without bothering to look at the numbers involved) you can say for certain that your answer contains an error. You can only measure a path in linear quantities: millimetres, centimetres, metres, sea miles, etc.

Checking your answer for its unit of measurement is a very useful test: it is quick, reliable and totally accurate.

For example: what distance would a sled travel in five seconds, starting from a stationary position, if its acceleration is 4 m/sec^2?

The necessary formula is:

$$S = \frac{1}{2}at^2$$

$$S = \frac{1}{2} \times 4 \times 5^2 = 50m$$

The test:

$$m/sec^2 \times sec^2 = m$$

I came across a gadget once quite by accident; it was three hinges, of the type normally used for hanging gates, fastened together at an angle of 120 degrees to each other. The gadget was a very handy stand for heating water over a fire, setting up a brazier over a fire, etc.

And then I thought to myself: what else, besides hinges, can be used in the way of "minor" technology?

When fitting out your work bench, an ordinary horseshoe can come in quite useful, as a brace, as a light anvil, as a tool for straightening nails, or as a rest for sawing on.

To the same end you might use a couple of spikes of the type used to fix railway lines to the sleepers.

A simple door spring, without further ado, can be set up as a universal hold-all for light-weight gadgets.

A small strip of tin can easily be bent into a shape which, when attached to the wall, will hold any tool you might want to hang on it.

I have given you a few examples, but my advice is: look at the simple things around you, look — as it were — for their "hidden possibilities". This approach is useful in itself, but also it will teach you to find unexpected solutions to constructional problems.

Dates on the Calendar

1803-1804

Various types of steam engines are built. The best known of them are the machines built by Blenkinsop, Murray, the Champey brothers, Brunton and Hedley.

1803

Robert Fulton builds a steam ship and tests it on the River Seine in Paris.

1807

Fulton's paddle steamer *Clermont* makes its first trip up the Hudson River.

1814

George Stephenson builds and tests his first steam engine.

1815

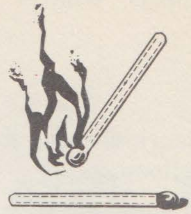
The first Russian steam ships are built, at Izhevsk in the Urals.

1817

Stearin candles begin to be used.

1819

The first crossing of the Atlantic by the steam ship *Savannah*, from America to England.



1825

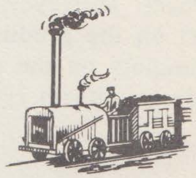
D. Cooper produces "stone matches", with heads made from a mixture of sulphur and white phosphorus.

1833

The appearance of wheel tractors.

Kammerer develops the technology for producing matches with heads made from yellow phosphorus.

1834



The Russian engineers Yefim Cherepanov and his son, Miron, build Russia's first steam engine.

Boris Semyonovich Yakobi, a Russian physicist and electrical engineer, builds a new type of electric motor.

1835

Gas lighting is introduced it St. Petersburg. Samuel Morse invents the telegraph.

1837

Paraffin candles come into use.

1830s-40s

Rails begin to be manufactured in Europe for building railways.

1842

The first round-the-world voyage by a steam ship.

1845-47

Robert William Thompson develops rubber tyres.

1852

Henri Giffard makes a flight in a steam-powered air balloon.

1855

Henry Bessemer discovers a new way of forging iron and steel.

1857

Pavel Matveyevich Obukhov, a leading Russian expert on the production of high-quality steel, is given a monopoly on the method, invented by him, of mass-founding uniform crucible steel.

1860

Etienne Lenoir invents the internal combustion engine.

Antonio Pacinotti invents an electric motor with a rotating ring armature.

1866

Two transatlantic telegraph cables come into operation between England and America.

1867

Christopher Latham Sholes invents the Remington typewriter.

Nikolaus Otto and Eugen Langen show their internal combustion engine at a Paris exhibition.

The first Pullman class sleeping-cars are built.

1869

George Westinghouse takes out a patent on his air brake.

The construction of the Indo-European telegraph link, between London and Calcutta, is completed.

1873

Alexander Nikolayevich Lodygin, a Russian electrical engineer and the inventor of a type of incandescent lamp, introduces electric street lighting in St. Petersburg.

1876

Pavel Nikolayevich Yablochkov, a Russian inventor and military engineer, takes out a patent on his "electric candle" — a new type of arc light without a regulator. He also builds a power transmission system for lighting purposes.

Nikolaus Otto builds a four-stroke gas engine.

Alexander Graham Bell makes his first successful version of the telephone.

1877

Thomas Alva Edison invents the phonograph.

Pafnuti Lvovich Chebyshev constructs a simple adding machine.

1879

Fyodor Abramovich Blinov, a Russian inventor, is given a monopoly on the manufacture of caterpillar tractors.

Edison invents an incandescent vacuum lamp with a carbon filament.

1881

Alexander Fyodorovich Mozhaisky, a Russian rear-admiral, after many years studying the problem of

8—76

flight by objects heavier than air, patents a steam-powered aeroplane.

Nikolai Ivanovich Kibalchich, a Russian revolutionary imprisoned for his part in the attempt on the life of Tsar Alexander the Second, develops, shortly before his execution, a plan for a rocket-propelled aircraft.

1882

Edison builds the first electric power station for street lighting purposes.

Nikolai Nikolayevich Benardos proposes a method of welding metals by means of electricity.

5

What Do You Know About Charles Goodyear?

I am fairly sure that you will never have heard of the name of Charles Goodyear. Nevertheless, his life, his work and his fate deserve careful study.

But first I would like to tell you about something that happened just over two hundred and fifty years ago.

In 1735 a French astronomy expedition found itself in darkest Peru. The scientists in the group discovered a tree there which produced a colourless juice, or — more correctly — a resin, which had the curious attribute of hardening in the sunlight.

The local inhabitants made footwear, dishes and many other everyday objects out of this resin. You will probably have guessed that I am talking about the rubber tree and rubber products.

The French expedition brought the rubber to Europe.

In 1811 the first rubber factory was opened in Vienna.

In 1820 French entrepreneurs began manufacturing braces and garters from a material of interwoven rubber and cotton threads. It was not long before Charles Mackintosh, in England, thought of a way of making waterproof cloth using a rubber base. His "mackintoshes", it is true, had one significant shortcoming: in winter they became stiff and unpliant, and in the summer they gave off such a smell that they had to be hidden in the cellar; but still, these coats were in great demand.

By the end of the 1820s around half a million pairs of galoshes a year were being sold in America.

1830 was marked out as the year of the "rubber boom" in the United States of America.

1833 saw the setting up of the "Rocksberry India Rubber Co.", making roofs for huts and caravans, head gear, footwear and clothes. Rubber factories began to spring up like mushrooms, and there were fantastic profits to be made in the industry.

But...

And Charles Goodyear's story begins with this "but": ...in the following summer it became apparent that all rubber products turned to a

runny, evil-smelling mash in the hot weather. In 1836 the losses sustained by the shareholders of rubber companies reached two million dollars.

Totally unaware of the entrepreneurs' troubles, Goodyear entered the New York shop of the Rocksberry Company to buy a rubber life-belt. He wanted to improve the valve used to inflate the belt. And he succeeded in improving it. But when he returned three weeks later and offered his invention to the firm, he was looked upon as a madman. The valve! What was the point of the valve if the rubber itself was useless! The ru-ubb-er!

Goodyear was neither a chemistry expert nor a technologist (he was a businessman for whom his inventions were merely a hobby), and he naively decided that putting the rubber right would not be all that difficult. Later he wrote: "I was blissfully unaware of the difficulties which faced me."

So he set to work. At first he used a rolling pin to roll out very thin films of untreated rubber, and he mixed into them such things as salt, pepper, sugar, sand, castor oil, and soup. At that time he was still able to joke: "If I test all the things on earth, then in the end I should come across something that will fit the bill."

Goodyear borrowed money, and even opened a shop selling "experimental" rubber products.

And then something extremely important happened: his assistant was sealing up a hole in his trousers — sealing it up, of course, using a piece of untreated rubber — and sat down and waited for the rubber to harden. And the outcome was that Goodyear had to use a knife to free the lad from his trousers. Rubber was, after all, really excellent stuff! If would have been simply criminal to stop his tests now!

Goodyear mixed the rubber with all sorts of things: nuts, cheese, ink, magnesia... Hang on! A pound of magnesia and a pound of rubber would give marvellous results. The mixture was supple and strong, like leather. Why, is not important. What was important, was that he had found the answer! And Goodyear made book covers and piano covers. The purchasers were delighted. But within a month it turned out that magnesia was not the answer. The inventor sold his shop, and his house, and ran into debt.

But still the tests continued: Goodyear boiled a mixture of the resin and magnesia in an aqueous solution of quick lime. This seemed to be the answer at last. The resulting material was smooth and strong. The newspapers heralded Goodyear as the saviour of the rubber industry. But within three weeks it was discovered that a drop of even the weakest acid, even apple juice, would neutralise the slaked lime, and the material would disintegrate.

Goodyear then subjected sheets of rubber to the steam from an acid mixture. The result surpassed all expectations. And again he thought he had found the answer. But then a financial crisis ruined his patrons. He himself fell into extreme poverty; he pawned the last remains of his belongings and continued his work.

His biographer wrote: "Someone once asked how he might find Goodyear, and he was told that if he saw a man in a rubber coat, rubber shoes, a rubber hat and carrying a rubber purse, and if there wasn't a cent in that purse, then he could be sure that the man was Goodyear."

Goodyear himself wrote: "For four years I tried in vain to improve and perfect the material which had so far defeated everyone who had ever been involved in its production. Many people suggested that if a man so stubbornly continued to work on this rotten stuff, then he deserved every misfortune that came his way, and he had no right to sympathy."

Overcoming want and hunger, and brushing aside the rumours that he was mad, Goodyear continued his work.

In the end he came to the conclusion that the rubber needed to be heated. That meant yet more experiments — with a fire and a stove. The amount of heat was varied... The result of this was that he discovered the process of vulcanisation.

And now let us leave the technical details of the production methods and look at the man himself. First of all let us look at what Goodyear said of his work: "I must admit that my discoveries are not the result of scientific research, but at the same time I cannot agree that they are just — as it were — pure chance. I would say, rather, that they are the result of persistence and observation."

Goodyear's whole life was given to this idea. All his life was a stubborn, brilliant struggle. The efforts of this remarkable man did not open up the path to outer space, nor would we call them epoch-making. But there are millions of motor-car wheels on the world's roads, all of them shod with rubber treads made according to the process discovered by Goodyear; there are endless conveyor belts in workshops, on building sites, in ports and post-office sorting rooms, all of them made from vulcanised rubber; deep-sea divers swim down to the ocean beds, scuba-divers swim around in underwater worlds, aircraft pilots lift the earth's ceiling enrobed in high-altitude anti-g suits, and all these things again are made possible by vulcanised rubber; surgeons wear very thin gloves when they operate, gloves that are elastic and weightless; chemists could not do without rubber protective wear; fishermen climb into their waterproof overalls... What more is there to say! Goodyear is everywhere: on the earth and under the earth, in the water and over the water, in the sky and in outer space...

And now we shall disregard the golden rule which says that victors are never judged; we shall try to learn a lesson not only from the positive side of Goodyear's life, but also from its negative side.

We shall not condemn this man of truly heroic character; rather, we shall draw our conclusions for the edification of his descendants.

Goodyear did not have the necessary background knowledge when he set about putting rubber to rights, and he paid for this all his life. He made hundreds of un-

necessary experiments, and he looked for the answer where science had already established that there was no answer to be found.

Goodyear believed in chance. And he was lucky on two occasions: firstly, when a piece of rubber came into contact with *aqua regia*, the strongest of acids, which gave him the idea of treating the rubber with acid; and secondly, when he saw a small piece of rubber which had been slightly burnt in the stove, which gave him the idea of using heat to treat the rubber. But it would have been just as possible for him not to have been lucky: the *aqua regia* could quite easily not have fallen on the one piece of rubber, and the resin in the stove could quite easily have been burnt to ashes.

Goodyear was forced — the way things were — to struggle on alone all his life. He carried a load which it would have been more natural for a whole team of researchers to carry. And the fact that he did not overstrain himself and fall down half-way was not only because of his amazing capacity for endurance, but to a great extent it was also pure chance.

Long live Goodyear! All praise to Goodyear! Our deepest respects to Goodyear! May we, his grateful descendants, always remember him!

But we shall not repeat his mistakes.

We shall try to take our cue from his character, but we shall not adopt his methods.

And as for success, chance, luck and fortune, we should tell ourselves at every opportunity that whoever works more, whoever is more persistent, whoever toils more selflessly, whoever believes more stubbornly, whoever is not stopped by the hurdles in his path ... that person will be more blessed by success, chance, luck and fortune than any fine talker, idler or passive observer could ever be. This too is a lesson to be learnt from the life of Charles Goodyear.

How to Test Yourself, How Not to Make a Mistake?

Very many young people, weighing up their path to tomorrow, are gnawed by doubt: how can they find out in good time and diagnose whether or not they have the ability, the talent and the potential for technical work. I think all the young people I have talked to on this subject can be divided into three basic groups.

The first group are those who think they were born to become engineers, to work with machines, and to construct new and undreamt-of contraptions. The reason for any doubts — if indeed any doubts should arise — is usually quite simple: they concern the question of what type of education and specialisation to choose; which would be better, say, to be an electrical engineer or a drilling engineer?

The second group are those who have no doubts whatsoever that it is interesting and important to be involved in the world of technology, and there is a good future in it; but to this they will cautiously add: "If only I knew for certain that I have the ability to do this sort of work! I don't want to go into it, only to regret my decision later."

The third group (the absolute minority) are those who are not so worried about how to discover and measure their ability and inclination but, rather, are afraid that they might "wear out their lives in an office". If only they could be sure that, by making the necessary effort, they would manage to become a chief engineer, be the boss on projects...

The first group is the easiest to give an answer to. The general direction, of course, must be mapped out in advance. Let's say you are interested in aviation; it would hardly be worth taking a course in a metallurgy college. There are much better means of finding your way in your particular field of technology. The first, and easiest, thing to do is to read the literature concerned with aviation construction, find out about the creative process in detail; and very soon you will learn to differentiate the work of an aircraft designer from that of an aviation industry technologist, you will find out the difference between an aero-engine designer and an aero-engine operator.

The second way of going about things is perhaps more complex and longer, but it is more reliable: before making any final decision, it would pay to take a job in the aviation industry. A motor mechanic, working for just a year at an aero-

drome, and a fitter or armourer, working for a year in a factory, keeping their eyes open to the things around them, can work out for themselves, on the basis of their firsthand knowledge, all the finer points of their chosen fields. Besides which, their practical knowledge of machinery, apparatus and instrumentation — even if this first acquaintance is only in the humblest of roles — will not come amiss in the future. This first brush with the real world of technology will give them experience, practice and a proper idea of what it is all about.

And one further comment: we live in an age when any field of technology requires a great many specialists, so-called "narrow" specialists. At aerodromes, for example, there are engineering operators, radio and radar engineers, repair engineers, and many other "hybrid" specialists whose work does not fit into a single field of engineering technology. But all these people begin their professional career in a more or less similar way: they begin by collecting general, rather than specialised, engineering knowledge.

Anyone who has chosen an aviation college as his starting point will be able to mould his direction more precisely as his studies progress; which, of course, applies just as much to anyone starting from any other learning establishment.

It is more difficult to give an answer to the second group. Science has, for a long time now, been trying to find a way to show exactly what natural inclinations and talents a person has. To this end a number of special research organisations have been set up, specialised laboratories are in operation, and there are thousands, perhaps hundreds of thousands, of experiments being carried out all over the world. But still no reliable system, apparatus or method has been found, by which it can be said with certainty about a person: "You, my dear W, should take up foreign languages; you, my dear X, would be best devoting yourself to science, research in the field of physics; you, my dear Y, will find that your path leads straight to a career as a film actor; and you, my dear Z, ought to go to a school of the culinary arts..."

Finding a person's inclination to a particular type of work, discovering his hidden — often deeply hidden — talents, is a difficult task which cannot always be solved. But still, I think, there are signs which can point quite definitely to a career in technology. I shall try to describe these signs briefly.

If a young boy or girl enjoys solving intricate problems in physics, sorting out difficult algebraic equations, and generally getting to the bottom of things in his or her school lessons — that is a good sign.

If a person is interested not only in the external appearance of a motor bike, car or television; if a person doesn't just want to go for a ride in a car, or just watch entertaining programmes on the television; if the person is also attracted by the thought of understanding the construction of the car's engine, or of following through the delicate interlacing of the television's electrical system — that too is a good sign.

If you enjoy using metal-working tools, making things not out of necessity, but simply for personal pleasure, and if in the process you try not to blindly copy a given pattern, but prefer to look for your own solution (even if it's only for mak-

ing kitchen shelves or a shoe-rack for the corridor) — that is a very good sign as well.

If a young boy or girl is a member of an amateur technical group (building model aeroplanes, boats, radios, or whatever) and consistently goes to its meetings for three years running without losing his or her enthusiasm — that is not merely a good sign, it is almost a direct pointer to the declaration: engineering is my vocation!

If you can deal with the simple diagrams which you are given to draw at school, and not only draw them neatly and clearly, but can also look behind the three projections of the object you are drawing and see, easily and effortlessly, the object itself, "creating" it in your mind's eye — that is also a good omen.

If you have enough patience not only to take apart your younger brother's clock-work engine, but also to put it back together once, twice, three times ... (after the first time there were a few "spare parts" left over, after the second time it turned out that you had not put the wheels on properly, after the third... But I hope you understand my point) — that too is a strong hint towards your suitability for a technical career.

If looking at machines makes you happy, if technology doesn't leave you indifferent, if you can admire, for instance, the precise work of an ordinary bulldozer, delight in the marvellous mobility of a gantry crane or tingle with excitement at the sound of roaring jet engines — throw aside your doubts and step boldly forward into the world of technology. You will find your place there!

And now a few words to those who want to be certain in advance that they will manage to become chief engineers.

Valeri Pavlovich Chkalov, a leading Soviet pilot of the 1930s, used to say: "If you are going in for a particular profession, then you want to be the best in it." It is quite natural for young people to match themselves against the highest standards. You would be quite right to do so. You should, of course, strive for the highest peaks, so long as your ascent is made honestly and honourably.

But I would warn this third group about one thing: when you are in the cinema, you will remember the names of the well-known or simply "fashionable" actors; but few of you will remember the other people on the screen, people who never have anything but "extras" to play, supernumarary roles, roles with few lines, or perhaps even only walk-on roles. And there are very many such people, far more than there are "stars".

If you hear the word "pilot", your mind will obligingly recall the names of the fifth ocean's heroes, the record-breakers, the champions, the men who opened up the Arctic airways... But behind every ten famous pilots there are thousands of ordinary men toiling away — in the very same profession — modest, humble people, unnoticed and often unnamed.

And the cosmos is not to be conquered by the handful of men who fly up in their inter-stellar spacecraft, but by a whole army of designers, technicians, builders, radio and radar operators, doctors, laboratory assistants, and many many other specialists of all fields.

The art of engineering moves forward not only because of the work done by the chief engineers; it has always moved — and will continue to move — on the combined efforts of genii, of talented, inventive and conscientious executors, and of simple, honest workers of all levels. Technology gives great scope for ideas, persistence, resourcefulness, daring, courage, and many other such qualities. The technical "front" is no narrower than the artistic "front", and indeed is probably wider. What you will manage to achieve in technology will depend on many factors, first and foremost on your own personal merits. An ancient sage used to say: "To gather your harvest, you first have to sow your seed; to win the battle, you first have to take the risk..."

In my opinion human happiness basically depends on whether a person is happy in his work, whether he gets satisfaction from what he does, whether he strides forward in his life or simply treads water. What is most important is his work, not his rank, his post or his formal position in society. It is possible to be a happy watchmaker, or an unhappy academician; the most important thing — I repeat — is a man's work, the cause which he serves.

Engineering is a boundless ocean: you may discover unknown lands there, lands which may henceforth bear your name, or you may drown. Don't forget that — you *may* drown. But so as not to let that happen you must learn to swim. And the sooner the better.

To give the reader some idea of things, and to help him or her to answer — albeit approximately — the question: "How can I test myself?", I have included a number of "Something to Think About, Problems to Solve" sections at various points in the book.

Of course, even if you can answer all the problems, questions and exercises in these sections without hesitation, that will be no reason to count yourself a fully-fledged engineer, but the easier it is for you to work out the answers, the greater will be your chances of not being left perplexed, lost and disappointed in the real world of technology.

The Melancholy Boy with the Large Album

I met him at an industrial exhibition.

The first thing I noticed was his album — a large folder in a hard cover of provocative red — then I noticed the owner of the album. He was a lad of perhaps thirteen, maybe a little more. You couldn't say he was fat, but he *was* well-fed. He had a round face. His hair stuck out on all sides, but was cut short. He reminded me of a doll — dishevelled, mischievous, but at the same time melancholy.

The boy looked for a long time at a new tip-up truck, found himself a place to sit down near a piece of garden machinery, and began to draw something in his album. I went on my way and probably wouldn't have given another thought to the melancholy boy with the large red album if our paths hadn't crossed again a number of times that day.

The scene was repeated: the boy either stood or sat near some machine or other, and drew something in his album. My curiosity was finally aroused and I involuntarily began to watch for the lad. At one point the object of his attention was an excavating machine: he walked round it once, twice, a third time, then stood for a while, craning his neck and looking at the tooth-edged scoop; then he began to draw.

While he was drawing, incidentally, he never looked at the real thing, the excavator or the truck, and that intrigued me even more.

The excavator itself was quite ordinary and found itself in the exhibition for the simple reason that its designers had managed to make their steel mole a little smaller than was the norm and, according to the explanatory notice, this gave it increased manoeuvrability.

I moved nearer to the boy and, totally disregarding good manners, looked at the album over his dishevelled head. And what did I see? His drawings took up the whole page, and there was the excavator scoop on the end of its boom (I must say that it was very true-to-life), next to it there was a spade (an ordinary garden spade) and ... a human hand. It was obvious that he had deliberately ignored the relative scales of these various objects: the scoop, the spade and the hand were all drawn of equal size.

Suddenly the boy turned round. His gaze met mine.

We are told that Thomas Alva Edison had a luxurious flower-bed around his house; everyone passing by came closer to look at the bright flowers which were so well groomed. And this despite the fact that to enter the garden a person had to pass through a very stiff turnstile.

One of Edison's friends asked him one day:

"By the way, what is that idiotic wheel doing in your garden, and why is it so difficult to turn?"

"I can assure you," Edison replied, "the wheel is no more idiotic than human curiosity. Everyone who turns it, automatically pumps water into a service tank up there on the roof. That's it, up there — all thirty-five litres of it."

"Are you interested?" asked the melancholy boy, and looked at me with his attentive, searching eyes.

I apologised for my unmannerly curiosity and said something insignificant and non-committal. We got talking.

Then we sat on a bench near a big, cool fountain. As I leafed through the red album the melancholy boy daintily ate an ice-cream in a cone and gave an explanation of his drawings.

It turned out that he did not draw all the machines, but mainly those which he found unsatisfactory. For instance, the powerful tip-up truck went into his album because he didn't like its body.

"They have again made a body which tips up backwards. That is bad, it just won't do. The driver has to drive in reverse, and waste time getting into position. And then, it is difficult to dump loads on narrow dykes..."

The boy was quite convinced that he was right, and it was impossible to dislodge him from the stance he had taken. I told him that tip-up trucks with side-tipping bodies were also being manufactured, but to replace all the backward-tipping trucks was, firstly, not an easy task and, secondly, was probably not all that necessary.

"No, they must be replaced. As you say, it is not easy — I quite agree, of course, but then everything has its own difficulties..."

He was a very strange boy. He reasoned like an adult.

He thought like a man of experience. His boyishness only showed itself in his stubbornness and in the way he ate his ice-cream.

My new acquaintance's objection to the excavator was even more serious.

"The construction is based on an unsound principle (that is exactly what he said: 'based on an unsound principle'): it is an ordinary spade scaled up two hundred and fifty times. And what's the result? First it scoops up the soil, then carries it, then takes an empty spade back again. Right? What it should be doing is digging up the soil and putting it to one side constantly..."

"Well, yes," I couldn't help interrupting, "but these machines 'of unsound principle' have built thousands of electric power stations and factories, they have dug in-

John Ericsson was one of the most talented and capable engineers of his time. A steam-operated fire pump, hydrostatic scales, a lathe for cutting files, a distilling apparatus, rotating gun turrets for warships, the locomotive Novelty — and this far from being a full list of his work.

"I work 365 days of the year," Ericsson used to say. We might also add that he worked for between twelve and fourteen hours each day, lived to be eighty-seven years old, and died at his drawing board. Ericsson built his first invention at the age of only eleven*: it was a model based on an original design for a saw-mill.*

numerable foundation plots for houses, and so on. Should we really criticise them so severely?"

The boy was in no way put off by my arguments:

"Of course we should! It is time to put them in a museum. Let's be grateful for what they have done in the past; but this is the sort of machine we need now!" And he showed me two drawings.

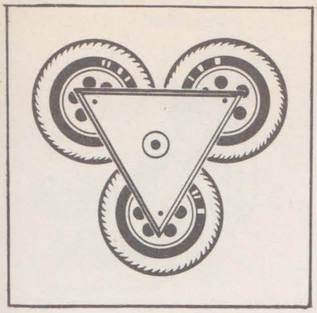
One I recognised as a continuous rotary earth remover: it had six scoops attached to a large wheel, and these dug into the earth one after the other, scooping out the soil onto a conveyor belt. The drawing showed something very similar to a giant mincing machine: two cutters chopped up the soil, and a spiral conveyor belt threw it away from the excavation point.

"Are you intending to build this?" I asked. And if only he had answered in the affirmative, I would probably not have been too surprised. Well, what can't you dream up at the age of just thirteen!

"No," said the melancholy boy. "I'm not intending to build anything at the moment, and I really don't know whether I will ever build anything worth while. I am just trying to understand how not to do things. I am collecting other people's mistakes."

Mistakes! Goodness, who doesn't make mistakes?! Even the great Aristotle taught his pupils that the speed of a falling object was dependent on its weight. He was convinced that a ball weighing four kilogrammes would fall ten times faster than a ball weighing only four hundred grammes. And no-one tried to disprove his idea for almost two thousand years. And only the genius of Galileo Galilei put the misunderstanding to rights.

And wasn't it Mikhail Vassilievich Lomonossov, the great Russian scholar of the eighteenth century, who wrote: "Metal is the name given to the light-coloured material which can be forged. There are only six such materials to be found: gold, silver, copper, tin, iron and lead. These can be divided into precious and base metals: the difference between these two types is that precious metals cannot be burnt to ashes using fire alone, whereas base metals can be so burnt to ashes." And this too was an error, a mistake by a genius.



But why did I have a feeling of antagonism towards this boy, who simply wanted to collect, learn and summarise other people's mistakes?

I made an effort to control myself, and continued to look through the red album.

One page has stuck in my mind in particular: it was drawn all over with nuts of various sizes and bolt heads, also of various sizes.

"What is this?" I asked. "A list of all the nuts and bolts you have ever seen?"

"No," the melancholy boy replied, "I have drawn on that page all the nuts and bolts from a single machine. Can you imagine the fitter's misery, having to change his spanner a hundred times just to make sure everything is firmly in place!"

I had no answer to that. And really, designers too often don't bother to think about the people who are supposed to use their machines. And, as though he had read my thoughts, the boy sitting next to me said:

"Have you ever noticed car owners struggling to change a tyre?"

"I've not only seen them, I've suffered from the problem myself!"

"And yet they could easily make wheels with detachable sides. You could take off the side piece, open out the tyre walls, change the inner-tube, and then it would be simple job to fasten the side piece back in place."

"That's how it has been done for aeroplane tyres for years," I commented.

"That's what I mean. You see..."

"Listen," I said. "Are you only gathering up mistakes, blunders and badly thought-out ideas, or are you collecting successful and imaginative ideas as well?"

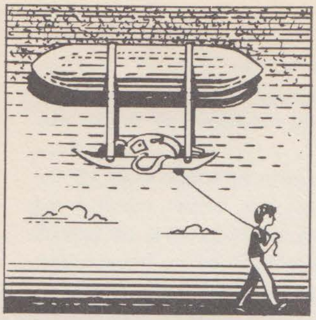
"Of course! The good ideas are also worth collecting. Only they are in my other album, the blue one."

"Ah, in your blue album. Hm! But have you anything new to offer of your own?"

"Not a lot so far," said the boy, looking to the ground. "If you like I can show you a few of them, but there aren't very many."

"OK! Let me see them."

The boy pulled a note-pad out of his pocket, flicked through its pages, and



then showed me something which, at first sight, seemed to be total nonsense: it was an equilateral triangle with an axle through the centre; a small wheel was attached to each of the points of the triangle.

"The triangular wheel makes movement over rough ground so much easier," he said, looking at me quite seriously. "On level ground it moves along on two of the wheels, and on rougher ground — over ruts, ditches and hollows — the whole triangle will turn. I made a model of it, and do you know, it works quite well. The principle could probably be used for things like tractors."

I could find no obvious absurdity in his idea; but a triangular wheel! It was devilishly unexpected, and all I could say was: "I-n-t-e-r-e-s-t-i-n-g..."

"Yes, I think it is interesting as well," the melancholy boy answered, like an echo.

Next he showed me a drawing of a car's rear windscreen; on it the numbers 20, 40, 60, 80, 100, and 120 were printed fairly large, and a sort of bar was drawn across the glass. There was also a lamp mounted on the car's roof.

"A reflector will show up the details of the speedometer on the rear windscreen. The white bar shows the speed. If it's on 40, then you're going at 40 km/hr; pick up speed and it will show 60 or 80. Any road-traffic policeman will be able to determine precisely whether or not you are breaking the speed limit."

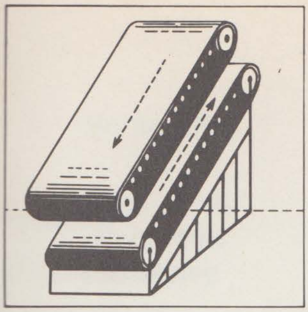
"And the lamp on the roof?"

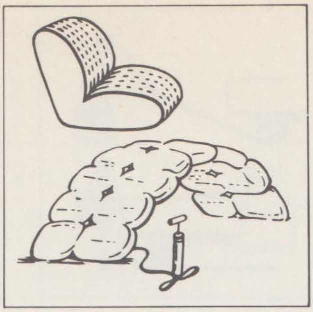
"The lamp comes on automatically when the arrow reaches 100. It is latched on a relay and will flash on and off. And people around will know at once that the car is going at a dangerous speed."

"Interesting," I said again, more and more amazed by the melancholy boy's ideas, his logic and train of thought.

"I think this may be quite useful as well," he said, turning over another page of his note-pad.

This time I was looking at a number of "cigars" tied together like a raft. Apparently, these were light, inflatable balloons. The "cigars" were harnessed to a sling hanging down from them, rather like the cords of a parachute. A rucksack, a tent rolled up like a bale, and various other pieces of camping equipment were hanging on two broad straps. This all floated some two or two-and-a-half metres





above the ground. I could fix the height by reference to the smiling figure drawn alongside, holding the "reins" in his hands.

"And this?"

"It is a small-scale aerostat to carry hikers' tackle and things like that. It is intended for places where a motor vehicle cannot go, and where the terrain is generally hard-going. It is inflated from canisters (you know the ones used for camping stoves? That sort). It can be pulled along by a person, or attached to a boat or a horse. I've given it three "cigars" to make it more reliable. It can be fastened to the ground when a day's travelling is over, and you can sleep on it like on an inflatable mattress."

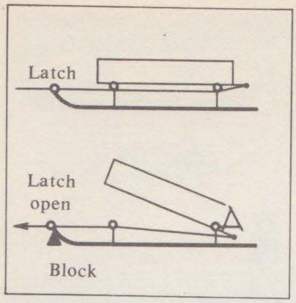
The boy continued to amaze me for a long time with his daring ideas, with his unorthodox views on the development of modern technology, but most of all with his sharpness of mind which would not allow him to accept the ordinary, habitual approach to things.

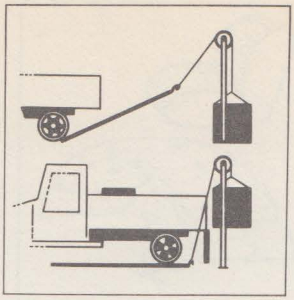
We parted the best of friends. He went off with the unhurried gait of a man of business, carrying his red album under his arm; as I watched him go, I thought to myself: "Norbert Wiener, the father of cybernetics, began to take a serious interest in science at the age of five, by the age of eleven he was put in the same class as eighteen-year-olds, and he took his first degree at fourteen. Who is it that I have just been talking to: a budding genius, or just an amusing little boy?"

I quite deliberately don't mention the name of the boy with the melancholy eyes, because abetting like that can be a dangerous thing. And besides, why should I add to the tribulations of a person who is only just finding his feet? Fame and glory, and heightened interest on the part of those around you, these are all a heavy burden even on adults, even for those with their feet firmly on the ground.

Pages from the Blue Album

An ordinary conveyor belt. It is used everywhere: on assembly lines, on building sites, for loading and unloading. But one thing it does very badly is lift objects, pull them up a slope. But if the belt is doubled? The two belts togeth-





er will not only pull things along, they will be able to hold on tight to whatever they are carrying. And the conveyor belt will immediately become even more useful.

I have studied the construction of car brakes. I find it strange that in all makes and models the brake shoes are arranged round the rim. This gives a friction surface which is relatively small, and the brakes must get fairly hot in use. It would probably be better if the brake discs were to press against the drum. Incidentally, in the very same models I noticed that the clutches are constructed on the principle I am suggesting.

Magazines fairly often show photographs of things filled with air: inflatable storehouses, garages, tents and the like. I think this is a very important step for future technology. Air can be put to work not only in life-boats, but also in furniture and equipment used by builders, geologists, mountain climbers and many other types of people. In general, things which can be taken apart and put together again quickly are very much in demand.

In January I was in the country and for the first time in my life I saw winter work in the fields. The tractor drivers were taking fertilizer out to the fields. Powerful machines were pulling huge sleds, as easily as could be. But what a job it was to unload them by hand! What is needed is an automatic tip-up sled; that would be the simplest solution.

And, by the way, any vehicle can load and unload itself, using a device like this at the goods inward and despatch points.

I have already suggested showing a car's speedometer reading on its rear windscreen. But I have another idea which will be of interest to both pedestrians and motorists: traffic signals fitted with clocks. The arrow on the clock would show how long the signal will remain on the colour it is on at any given moment.

Something to Think About, Problems to Solve

(*Answers*)

1) The glass tube is the same sort of device as a chimney over a furnace. By creating a draught, this transparent tube improves the conditions for the wick to burn in. The first person to suggest a "glass" tube over the wick of an oil lamp was the great Leonardo da Vinci. True, his "glass" was not glass, but a thin wire netting; nevertheless, the purpose and construction of da Vinci's device was no different from its modern equivalent.

2) The five 3s can be set out as follows:

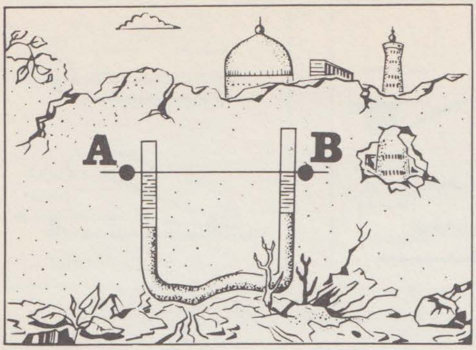
$$3^3 + 3 + \frac{3}{3} = 31$$

3) Take any dish into which the fork will fit entirely, and fill it up to the rim with water. Now put the dish on a plate or in a bowl, and put the fork in the water. You will realise, of course, that some of the water will spill over into the plate or bowl. Collect this water in a measuring jug, and the volume of the water will equal the volume of the fork.

4) You should put your leaf or irregular shape onto a piece of graph paper (or, at least, onto a piece of paper with lines ruled both horizontally and vertically). Then draw round the contours of the leaf or shape to be measured, and count up the number of squares inside these contours. So as not to miscalculate, first of all put a cross in all the complete squares and make a note of how many there are of them. Next, set about making up full squares from the partial ones around the edges, putting one or more together as necessary, and make a note of how many of these "assembled" squares there are. Add the two sums together and you will have the overall area of the leaf or shape.

5) To solve this problem easily and quickly, all you need is a rubber tube of reasonable length and two glass tubes to fit tightly into the ends of the rubber. Fill the tube with water and affix one end to point A. Affix the other end to another place on the wall and mark this point B. The level of water in one glass tube will exactly correspond to the level of water in the other. Join points *A* and *B* with a straight line and you will have the required horizontal.

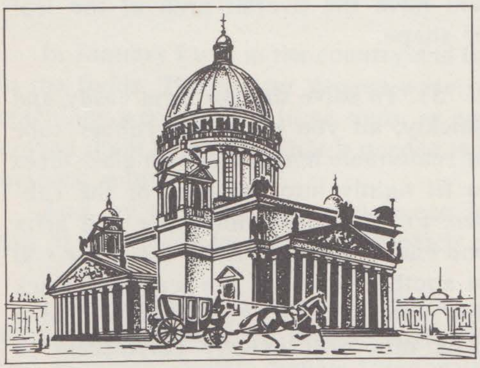
Incidentally, when St. Isaac's Cath-



edral was being built in St. Petersburg (now Leningrad), the builders were faced with a similar problem: they had to cut all the foundation piles strictly level.

The chief architect, August Montferrand, ordered the foundation trench to be filled with water. When the surface of this artificial lake reached the required level, the piles were all marked with charcoal. Then the water was pumped away and the piles were cut off at the black marks.

Water is an ideal substitute for a spirit level!

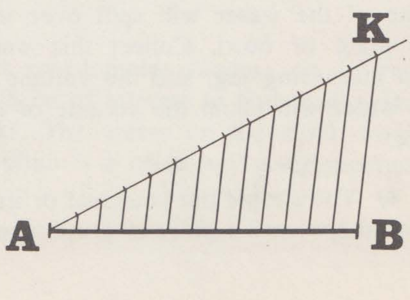


6) If you rub a nail or a piece of wire with emery paper or any other rough material, it will grow quite warm very quickly. Our ancient ancestors used to make fire by means of this very same sort of friction. Of course, solving this problem is nothing complicated, but ... never forget the experience of times past. Sometimes this experience can be extremely useful!

7) This is what the completed table looks like:

2 + 6 + 3 + 4 + 5 — 8 = 12
9 — 8 + 1 + 3 + 5 + 2 = 12
8 + 6 + 1 — 7 + 9 — 5 = 12
3 — 2 — 1 + 4 + 5 + 3 = 12
7 + 9 + 8 — 4 — 3 — 5 = 12

8) Let us call the length which you want to divide — *AB*. Draw a line from point *A* diagonally to the line *AB*, and call it *AK*. On the line *AK*, beginning at point *A*, draw thirteen equal segments (the size of these segments is not important, what is important is that they should all be equal). Join the end of the last segment to point *B*. Then all you have to do is take a ruler and set square, and from each point on the line *AK* draw a straight line parallel to *KB*, to cut the line *AB*. These parallel lines will divide the 8 1/2 centimetres into thirteen equal parts.

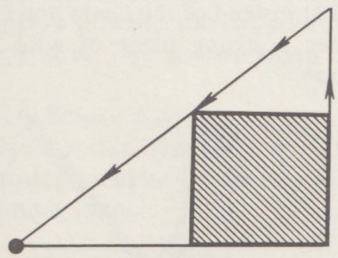


9) Filling in the missing figures:

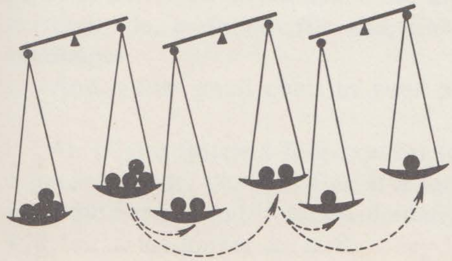
7 + 2 — 4 = 5
\+ — + +
5 — 2 + 5 = 8
— + — —
7 + 5 — 6 = 6
= = = =
5 + 5 — 3 = 7

10) A multiplication table.

11)



12) Put four balls on each pan of the scales. Whichever four are lighter, divide into two pairs. Put one of these pairs on each pan. Whichever pair is lighter, divide again and weigh a third time, with one ball on each pan.



13) **4 + 9 + 2 = 15**
+ + +
3 + 5 + 7 = 15
+ + +
8 + 1 + 6 = 15
= = =
15 15 15

Incidentally, each of the diagonals also adds up to 15.

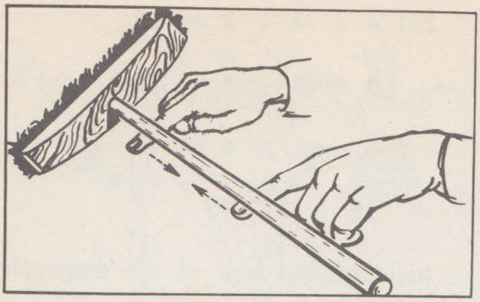
14) A sewing needle can float. But only in particular conditions.

Take a glass and fill it as full as you can with water, preferably so that the water even comes a little above the rim. Now take a needle and, very carefully (the best way is by moving it from the rim to the centre), lower it onto the surface of the water. The needle will not sink, it will swim.

Why? Because the water has a particular property: its upper surface is a film which has what is called surface tension. And it is this tension which holds the needle afloat.

15) This too is explained by surface tension. The surface tension of pure water is greater than of soapy water: so, the film of clear liquid "stretches" the bubbles in all directions.

16) Holding your forearms out horizontally in front of you, rest the brush on your index fingers so that it keeps its balance. Then start gradually moving your fingers together without allowing either end of the brush to tip over. The

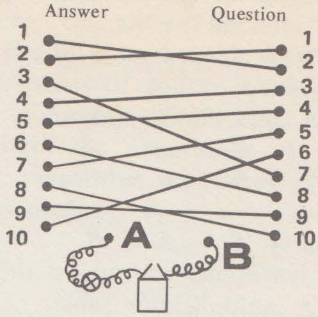


point where your fingers meet will be the centre of gravity.

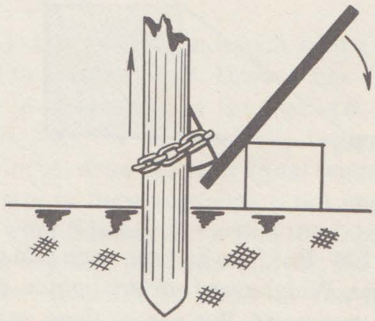
17) The easiest way is to dip your matches in melted paraffin wax (for this will need some candle stubs and an empty tin can). And, by the way, matches treated in this way are also better than untreated ones in windy conditions.

18) 7 — 5 — 2 = O! That is the stumbling block: you should never "cancel out" to nought.

19)



20) I think the drawing answers the problem sufficiently clearly. I would only add that instead of the chain you could use either a strong piece of wire or a good rope.



Some Useful Hints

We have already mentioned the value of experience, and I have advised you not to let slip any useful finds by other people, no matter how small these finds may be. If you have already started your "experience money-box", let me drop one or two small coins into it:

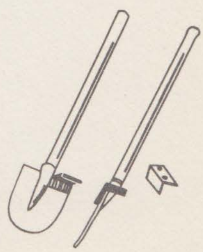
1) Before painting a metal pipe, rub it down with a cloth soaked in vinegar, then let it dry. This preparatory "cleaning" will help the paint to adhere better and to stay on much longer.

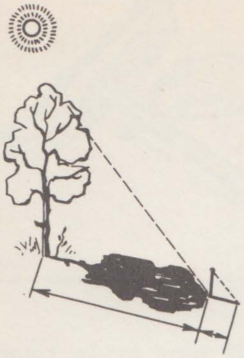
2) If you have to do a lot of drawing (and especially of radio or electricity circuits), make yourself a stencil for the most common standard symbols. You can cut out the contours of the symbols in a thin piece of acrylic plastic or celluloid. You will find it easier to draw your diagrams, and your symbols will be a lot neater.

3) If you glue together several layers of plywood of different sorts and let them dry thoroughly under a press or in clamps, you will have an excellent material for making small, strong and beautiful objects. The resulting piece of wood can be cut with a saw and smoothed off with a rough file, a smooth file and, finally, with a piece of sandpaper.

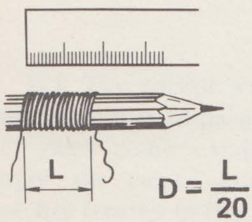
And a few small coins in your big money-box:

4) If you fasten a foot-bracket to the upper edge of a garden spade, you will find it a lot easier to turn over even the hardest soil. And, incidentally, your garden boots will last a lot longer as well.



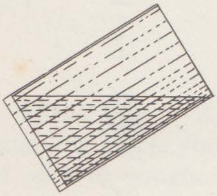


5) You can measure the height of a tree (or of a house, or of anything whose top is out of your reach) quickly and accurately by means of its shadow. For this you will need to put a small pole in the ground at the end of the tree's shadow; the top of the pole should be one metre above the ground. Then if you measure the length of the tree's shadow, divide this by the length of the shadow from the small pole, and you will have the height of the tree.



6) If you need to find the diameter of a thread or thin piece of wire and you don't have such a fine measuring instrument, what can you do?

Wind the thread or wire, say, twenty times round a pencil, and measure the length of pencil covered by the thread or wire. Divide this length by twenty and you will have the diameter you are looking for. But remember, for this to be accurate, you must wind the thread or wire tightly, each turn to be close up against the one before it.



7) How can you measure exactly half a glass of liquid without using a measuring jug or anything of that kind? The picture shows the answer to this quite clearly.

It is practically impossible to have in your home the full range of tools and gadgets which you may ever want to use. Taking the example of "lever" tools (pliers, flat-nosed pliers, combination pliers, tongs, scissors, forceps, tweezers, etc.) — there are over five hundred types available; and then there are drills as well, and files of all shapes, sizes and cuts...

I would therefore recommend you to learn from people with experience and work out for yourself the construction of the simplest and most indispensable gadgets. To give you a few examples:

If you glue a strip of emery paper onto a thin, smooth lath of wood (250 x 20 x 5 mm), you will have made yourself an extremely handy tool for finishing whatever you are making in metal.

Make a note just in case: a red-hot piece of wire is a very good substitute for a fine drill bit when it comes to

making holes in thin boards, plywood and many types of plastic.

Ordinary wooden wedges can be used in a domestic workshop in place of clamps and presses.

Small nails, screws and bolts are often difficult to pick up in your fingers but if you use a magnet or a small lump of plasticine, you will manage it a lot better.

I have gone through a few useful gadgets, and mentioned only odds and ends of examples: now you should think for yourself, and look for your own ideas, and I am sure that you will be able to expand my list easily.

Defects: take the simple example of your torch ceasing to work. What can you do to put it right? You can, of course, take it apart entirely and check all the parts in one go. A torch is not a particularly complex construction, and you might think you can easily find out what's wrong with it. But you would be better taking a logical approach:

1) The torch doesn't light up because the contact with the battery is weak. You check the contact, but still the torch doesn't light up.

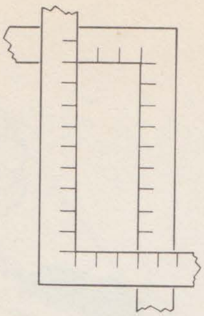
2) The bulb might have gone. You put a new bulb in, but still the torch doesn't light up.

3) But what if the battery is flat? You take the battery out and test it with a bulb. It lights up, so the battery is OK.

4) That means the switch on the torch isn't working, because your checks have shown that everything else is OK.

I repeat: a torch is the simplest of machines. And if you start having to look for faults in more complicated constructions, then taking a logical approach becomes that much more important. Otherwise you may never find the fault; if you go rushing about from one component to another, testing the fifth one, and the tenth one, then the fifth one again, you will never get the job finished and you will just be wasting time.

For a bit of practice, try setting out an approach for finding what's wrong with an electric iron. You can begin with: "The iron is switched on but doesn't warm up..." Or another one: you press the door-bell, and it rings; you take your finger off the bell, but it keeps on ringing...



If one of your pleasures is photography, or if you have to cut a lot of paper to size, make yourself two L-shaped corners out of stiff cardboard and mark their edges in centimetres. This simple device will, firstly, allow you to cut out rectangles of any size with no trouble at all and, secondly, will stop your paper from slanting, because each corner will be strictly 90 degrees.

If you have to paint an electric lightbulb (for decorations, for instance), the following may be of help: aniline paint can be thinned in water glass (sodium silicate solution), but not so as to have too thick a solution. You need only put a thin coating of this on your lightbulb; then let it dry, and the job is done. The bulb will shine in all the colours of the rainbow.

And now some advice for those with little brothers and sisters.

Small children play with dolls, toy animals, toy cars, and the like. Some have more toys than others but not one of them ever has enough "auxiliary" objects to play with. So, one uses a chess-board as a tunnel, another takes a shoe-box and pretends that it is a house, a third turns a soapdish into a boat or a trough, and so on.

But is it really that difficult to make toy trees, houses, road signs, traffic lights, furniture, wells, and many other "extras"?

Put your imagination to work, remember what stage props look like, think for a while and I am sure you can achieve quite a lot.

Besides adding to your little brothers' and sisters' fun, your hands will become practiced in making all sorts of little things. Your little brothers and sisters will stop pinching your things — your hockey stick, drill or hammer. And you will earn the gratitude of your parents.

All in all, you will achieve quite a lot!

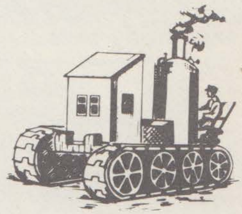
Dates on the Calendar

1885

Gottlieb Daimler takes out a patent on his design for a petrol engine, and he builds a carriage with this engine. It may not have been the first automobile, but it was the closest ancestor of the modern motor car.

1888

Fyodor Abramovich Blinov builds a steam tractor.



1894

The first international automobile race is held in France.

1897

Rudolf Diesel builds a compression engine with autoignition.

1901

Experiments in radio-telegraph are carried out across the Atlantic.

1903

Konstantin Eduardovich Tsiolkovsky publishes his paper *Research of the Planets by Means of Jet-powered Rockets.*

The Wright brothers, Orville and Wilbur, make their first flight in an aeroplane which they themselves have built.

1909

N. Gerasimov puts forward a project for a turbojet engine.

1911

Alexei Nikolayevich Krylov, a well-known Russian shipbuilder of the time, and R. M. Vetser build a mathematical machine for integrating differential equations.

1913

Henry Ford introduces a conveyer belt into his factory.

1914

Robert Eduardovich Klasson uses hydraulic power for excavating peat.

1915

Hugo Junkers builds an all-metal aeroplane.

1919

Mikhail Alexandrovich Bonch-Bruyevich, the most outstanding Soviet radio engineer of the time, builds powerful water-cooled radio valves.

The name of Henry Maudslay is usually remembered together with that of Andrei Nartov. They were both outstanding mechanics of their time, and they both put a great deal into improving the lathe.

Henry Maudslay was born in Woolwich in 1771. At the age of twelve he began working in a gun-factory, filling cartridges. Then he worked as a carpenter, and later went to work in a smithy. Here he became well-known to the customers, and when Joseph Bramah — the inventor of unique security locks — was looking for a skilful craftsman, Maudslay was pointed out to him as a lad who could turn his hand to everything.

So Maudslay began working for Bramah. At the age of eighteen he became a master craftsman, which was a rare achievement in those days.

Maudslay was paid thirty shillings a week; and when his request for an increase in his meagre wage was met with refusal, he decided to take on work for himself. In 1797 he opened his own workshop on Oxford Street, and here he built a lathe carriage which laid the foundation for far-reaching changes in the whole machine-building industry.

Incidentally, Maudslay continued to work alongside his craftsmen and pupils even after he had become the proprietor of a flourishing business, and he never in any way abused his privileged position.

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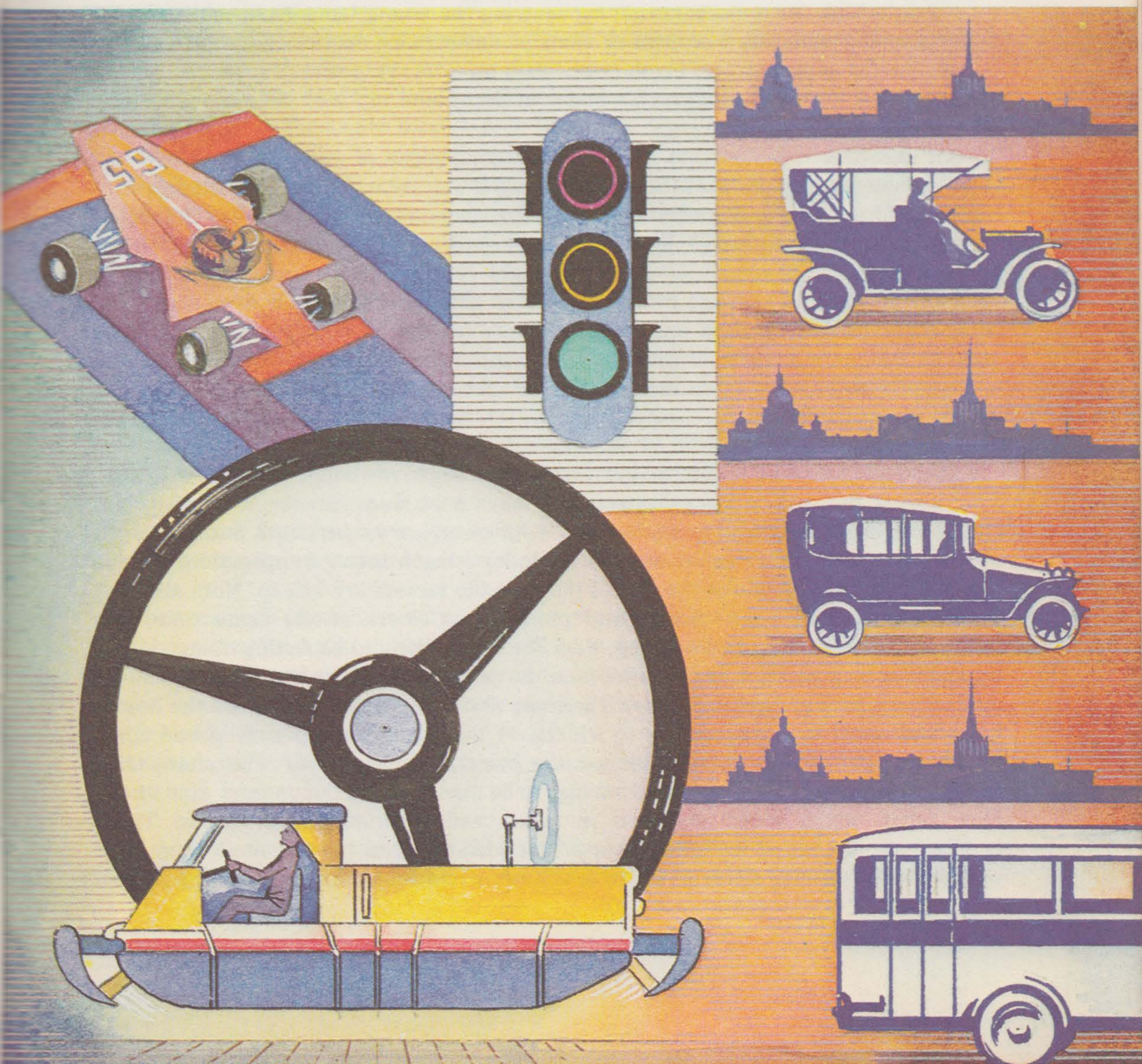


The Uninvited Sequel to an Unexpected Meeting

I didn't think for a moment that my meeting the young lad with his collection of other people's blunders would have such an unforeseen sequel.

We parted company and he went his way; then I caught myself looking at every new machine, every gadget, device and tool that came my way — looking at them all through his eyes.

An excellent machine tool, a forward-looking piece of equipment: so why are the components brought to it for working on a low-level trolley so that the operator has to bend down to pick them up? Could the components not be fed in through a chute directly to the chuck? It would not be particularly complicated to arrange, and not particularly expensive either: it might cost ten roubles to save thousands.

I get into a mini-bus and notice: to change gear, the driver has to put his hand somewhere behind his back and fumble blindly for the lever. It's a disgrace! What can the designers have been thinking of? In summer it is merely inconvenient but what must it be like in winter when the driver isn't just wearing a T-shirt, but a warm jacket which, being thick, will restrict his movements? And really, what would it cost to put the gear lever, say, under the dash-board?

Blunders, mistakes and technical absurdities began to haunt me at every turn.

Another thought: in your flat you may have a vacuum cleaner, a washing machine, a floor polisher and a ventilator — four electrical home-helps, and each with its own motor. And how many minutes each day is each motor in operation? Maybe ten, maybe twenty. And for the rest of the time the motors are asleep. Note also that you don't vacuum your carpets and polish your floors at the same time; and if a house-wife is doing her washing, then she is not likely to be setting about tidying up and cleaning her flat at the same time. So why not separate the motor from the operational part of each machine? Then one motor would suffice for all the home-helps and could be connected up to whichever machine was required, as and when it was required. In short, why not use the principle of a tractor with changeable trailer units? Just think of the huge savings to be made, taking the country as a whole. How much space could be saved in flats with restricted floor areas! There is definitely something to think about in this idea. A light, purpose-built connector would also allow the motor to drive a sewing machine, a small bench-drill and, if

necessary, it could operate a pump, a mincing machine... Basically, it is a suggestion worth looking at further.

When I read magazines, newspapers and pamphlets about technological innovations, I don't — as it were — pick up my pencil to make notes only of the blunders and failures, but also of the things that show imagination, usefulness and inspiration.

And these are some of the things in my notebook.

How often we see a block of flats newly built, bright and clean. Then the winter comes and goes, and by the end of spring you don't recognise the building: the walls are dark and covered with suspicious-looking stains — can't we repaint it? So it gets painted.

Yet another year, and a sad memory is all that's left of the new coat of paint. But can we do something so that we don't have to keep repainting it?

It seems that we can. For this, very thin sheets of tin plate are coated in coloured enamel, and these sheets are used to face the walls. Now after every shower of rain the building sparkles, it is washed clean and bright as new.

The economics of this are that, although the tin and enamel are expensive, and although the amount of work involved in facing the walls doesn't come cheap, nevertheless the paint, and the efforts spent on the so-called cosmetic repairs, are no cheaper.

OK? I think it's very much OK.

The number of pipe-lines is growing year by year. Millions of tons of oil and oil products, millions of cubic metres of natural gas flow along these invisible rivers. Rivers? Rivers!

It was perhaps this comparison that gave birth to the idea of using these man-made streams in the same way as natural rivers have been used since the beginning of time — as transport routes. It was tried, and it worked.

By way of an experiment, tin cans were transported along an oil pipe-line. And as the specialists reported, it was convenient, economic and quick.

When ten such ideas, or twenty, come to your attention all at once, your spirit willy-nilly perks up and you think to yourself: how resourceful man is, how intelligent and imaginative, and perhaps the sphere of his activities is — and always will be — infinite, because life itself is constantly moving forward, giving rise to innumerable changes and transformations.

And you expect ever new discoveries, quite certain that they will come, that they cannot help but come.

Perhaps one of the worst things that can happen to a driver on the road is a puncture — particularly in a front tyre, and particularly at high speed. People have

Frederic Joliot-Curie, writing in the first half of this century, gave the opinion: "If we could use just ten percent of the sun's radiation falling on a surface equal to the area of Egypt, then the amount of energy thus produced would be equal to the aggregate amount of energy currently being used in all the countries of the world."

Need we be reminded that solar batteries exist and that they are already working successfully in outer space.

been trying for a very long time to make tyres totally safe, they have dreamt up all sorts of things, but tyres are still only a-l-m-o-s-t safe. Alas, almost!

What can we do to make them totally safe?

What if we pump in through the valve, together with the air, a foamy substance which will harden and yet remain sufficiently elastic?

Then the thousand of tiny cells of the hardened foam will retain the necessary tyre pressure: and there can be no chance of a puncture because there will be no air to burst out.

Today this is no longer merely an idea — it is an engineering solution.

A forest is planted from seedlings; but just imagine the work involved in doing this planting by hand. So, we need to mechanise the process. But the seedlings of trees won't fit into an ordinary sowing machine. Engineers, however, have come up with a novel approach: the seedlings are placed at small intervals on a broad band of paper, they are covered with another band of paper just like the first, and the two bands are glued together. Then the future trees, in their protective paper, are rolled up and sent to the sowing area.

All operations from beginning to end are mechanised. The forest is planted quickly and continuously; and when the seedlings take root, the paper rots away and all further processes follow their natural course.

Digging an irrigation channel is, of course, not an easy job at all. But it turns out that maintaining it is far from being as straightforward as it might appear at first glance.

The channel has a number of terrible enemies — algae, reeds and weeds. If you don't keep up the fight against them, they can very quickly choke the channel and block up the flow of water entirely.

Until now algae have been dealt with by means of tractorised trawl-nets, chemicals have been used, unusually greedy fish have been "invited" to take part in the work, and people have even tried breeding coypu in the channels. To wage this war, the people whose job it was to look after the channels were not only put to great

Thomas Young began to read when he was only two years old. By the age of six he had learnt geometry, and by the age of eight he was making geodesic studies. Young knew many foreign languages. All his life he strove to increase his practical abilities: he learnt to play all musical instruments, he studied optics, acoustics, shipbuilding, astronomy, physiology, medicine, zoology, philology, and still found time to be a circus performer — he was an acrobat and tight-rope walker.

expense, they were also under constant pressure and needed to apply continual effort to the task.

At the same time, coal-tar pitch was considered to be a totally useless industrial waste product. It only took up valuable space. But then someone discovered that if the walls and bed of a channel were treated with hot pitch, then the channel would generally remain clear for about three years, and sometimes even up to five years. Pitch is cheap and is equally destructive to rushes as it is to sedge.

The list of what has been done, discovered and invented can go on for ever, just as much as the list of what has not yet been solved, what has so far evaded man's imagination. There will always be solved and unsolved problems in the world; these problems will live side by side, they will fight amongst themselves, they will disappear and reappear, they will change, some will suddenly take on particular importance, threatening mankind and helping mankind, making people seek and think, toil and celebrate.

If you choose engineering as your life, don't just pass by what your predecessors have done, don't remain indifferent to what they haven't done and what they have done badly.

A Sense of Time, an Ability to Foresee, and a Readiness to Fight

Heronus of Alexandria lived around two thousand years ago. He was the outstanding scholar, mechanic and engineer of his time. The apparatus known as Heronus' Sphere is permanently written in the history of technology — a spherical vessel fixed onto two supports and having two nozzles attached to it. Water was poured into the vessel and heated. The steam arising in the sphere was forced out with such power that the whole system was made to rotate.

But surely, this is a steam turbine!

Of course it is: Heronus' Sphere was the prototype of the steam turbine, its distant ancestor. So why did the prototype not turn into the real thing and make itself useful to mankind? Why did it remain just an ingenious toy, imaginative and curious, but still only a toy?

Above all because Heronus was ahead of his time.

His society, which had cheap slave labour at its disposal and which was living an unhurried life, did not have to develop highly productive technology.

So Heronus' Sphere remained just a toy.

In those distant times, incidentally, there were many other important natural phenomena discovered which were not put to real use. It was discovered, for instance, that when air was heated it was capable of displacing a liquid. This discovery of an important principle of physics came into the hands of the priests and holy fathers, who were only too pleased to be able to use it for a most effective optical illusion: they lit a sacrificial fire before the statue of a god; some time would pass and tears would begin to fall from the eyes of the holy figure. The believers who cast themselves down before this "miracle", of course, were not to know that in the sacrificial altar was an enclosed vessel attached by a thin tube to a small reservoir in the head of the statue. The air, warmed by the fire, entered this reservoir and displaced the liquid there; it was this liquid which flowed as holy tears. The same principle was also used for operating automatically opening doors, and other "miracles", in temples. Thus, another call for an ingenious concept to be used in a real machine was left unanswered.

The engineers of antiquity, although they knew a great deal, were far from the peak of human knowledge: nevertheless, they could build complex tunnels, amazing

systems of water-pipes, and a great many levered machines; they learnt to use the propeller, constructed a counter to measure the distance travelled by a carriage, and invented surgical instruments which were very similar to modern ones; they managed to make "remote-controlled" dolls, and even collected them together into a whole theatre.

And it is the same picture over and over again: society adopts only those inventions, constructions and discoveries which it particularly needs and which it, as a society, simply cannot do without any longer. That is why the drafts and sketches of Leonardo da Vinci, offering people the parachute and the outline of a helicopter, for so long remained just drafts, sketches and preparatory calculations which astound even us, for whom aviation is a part of everyday life. And in the days when these ideas were born, mankind had only just learnt to move around the surface of the earth: sails and oars were quite adequate for travel on water, and it was beyond the imagination of all but a very few men to take to the air. And besides, technology was not sufficiently developed at that time to set about the practical realisation of many of the Italian genius' ideas.

In our most technological of all technological ages, the art of engineering can be divided — as it were — into two echelons. The first echelon is forward-looking, leading into the distant and not-so-distant future; the second echelon is closer to home, and its sphere of influence is today and — perhaps in a little way — tomorrow.

And you must keep this division clearly in mind.

The question, "In what direction, then, should my work lie?", I cannot answer for you. Mankind as a whole needs ideas of how to put buildings on the moon, the technology to build inter-planetary spacecraft and the scientific ability to make artificial organs for living organisms, as well as new types of the most down-to-earth pots and the more advanced technology of preserving perishable foodstuffs.

To answer the question, "So, in what direction should my work lie?", I think we need to start with the inclinations, abilities and character of the person who intends to devote himself to technology.

A person may be ambitious and enjoy impressing those around him, he may be susceptible to praise, he may be impatient and value above all else the visible

It was established long ago that about once in eleven years bright flashes can be observed on the surface of the sun. But there is an immense gap between even the most accurate fact and a regular scientific law.

How could this observation, so important for astronomy, be checked? By waiting? How long for: for ten periods of eleven years, or twenty, or perhaps a hundred?

John Herschel was an astronomer who could not wait that long, so he set off ... for the London Stock Exchange, and asked for details of cereal prices over the last few centuries.

results of today's efforts and of yesterday's sleepless nights: such a person will find life hard in the first echelon, no matter how brilliant his talent. But there is a type of person who, above all, appreciates searching, a type of person whose greatest pleasure is finding answers to intricate questions; it is not so important to know "whether the house will be erected or not", what is important is to discover, to unearth all the facts. It is important to carve out the truth, explain the inexplicable, and construct what cannot be constructed by normal methods. The words of Albert Einstein are quite appropriate to these people: "The joy of seeing and understanding is the most wonderful gift of nature." These are the people who belong in the first echelon.

I was once in a scientific research institute where the young researchers had set their wits to a far-reaching question — they were trying to break the hereditary code and thus find a way of influencing living nature. Working alongside the biologists there were electrical engineers, physicists, pure mathematics experts, expert mechanics and talented metal workers.

It needs the effort of a team to get the better of modern science, a team with the widest possible range of specialist knowledge.

We talked of various things, and then I asked:

"What do you think — when might your work have practical results?"

"It's difficult to answer precisely, there are too many unknowns involved, but, very approximately, I would say maybe in fifteen or twenty years."

I looked at the leader of the group with undisguised horror. And I thought to myself that by that time he would be over fifty. But he didn't seem to be bothered by such an idea, and he went on:

"The more distant problems are always difficult to solve; we need to foresee a great deal, a lot of experiments have to be carried out and, whether we like it or not, we will make mistakes."

Involuntarily I recalled a line from my favourite author, Anton Chekhov: "...It is a hard life for the person who has the courage to take the first step along an unknown road. The vanguard never has it easy."

A person may be more attracted by resolute action than by unhurried

Analysing the summary of the cereals market, Herschel established that fluctuations in prices occurred exactly in line with the activity on the surface of the sun; he had thought that the solar activity could not but be reflected in the results of the world's cereal harvests. So, the eleven-year cycle could be quite safely counted not only as an accurate fact, but also as a regular phenomenon.

Without going too deeply into the importance of this phenomenon for astronomers, have a think about Herschel's way of reasoning, its subtlety, imagination and simplicity. His method is worthy not only of admiration, but also of imitation.

contemplation and painstaking penetration into the heart of a matter, a person may be quick off the mark and easily stifled by the endless repetition of calculations and computations of protracted desk work, a person may know no greater pleasure than to see his idea embodied in metal, concrete, wood or plastic: such a person will probably be more at home in the second echelon. And it is very important to feel comfortable in your chosen field. Assurance that you are doing what you are capable of and what you ought to be doing — this is perhaps one of the first conditions for achieving success.

But neither the first, nor the second, echelon will free you from the necessity of fighting.

Against what and against whom?

First and foremost, you will have to fight against ignorance, against resistance on the part of your materials, against the results of experiments literally slipping out of your hands, against your own doubts... Also you will not avoid the fight against the inertia of people's way of thinking, against the power of habit, against the tendency to cast doubt on everything which has not yet become ordinary.

Man does not find it that easy to break his habits. If you root through old magazines and newspapers you will find a fascinating consistency: some two hundred years ago the wittiest cartoonists aimed their ridicule most commonly at the builders of steam-powered engines; later the ridicule was directed at the pioneers of electricity; later still — at the automobile; then it was the turn of aeroplanes. The new tends to frighten because, it is seen as unreliable and suspicious.

At the beginning of our century a certain American school was once visited by a highly respected bishop. His Grace remarked to the head-master:

"As I understand it, mankind has not another single basic natural law to discover; therefore you should base your curriculum not on science, but on theology."

"But I am of a different opinion," objected the head-master, "science still knows far too little. And I am convinced that it will one day give man the ability to fly like a bird."

Pierre Martin gave the development of metallurgy in the nineteenth century one of its greatest boosts, with his discovery of a new way of forging steel.

Many years passed and the metallurgy companies, which had introduced furnaces of Martin's design, were making immense profits. And then it was decided to raise a memorial to Martin. His date of birth, 1824, was carved on it, but a dispute arose as to the date of his death: some said 1909, others — 1910. The arguments went on for two years, but Martin was still alive! At the age of eighty-six and forgotten by everybody, he was dragging out a beggarly existence in a Paris suburb. Pierre Martin died in 1915.

The bishop became extremely incensed at this:

"Those words will see you burning in hell for eternity!"

The bishop's name was Milton Wright. He was the father of the Wright brothers, the first Americans to build and fly in an aeroplane.

Need I go into the details of how difficult it must have been for Orville and Wilbur Wright to pioneer the way to the sky, having a father like the bishop Milton Wright?

For all engineers worth their salt, for all those going forwards, it is never easy, and there is no resistance on earth more stubborn or persistent than human resistance. In probably half the biographies of outstanding technologists and engineers you will find the story of an agonising struggle to overcome endless difficulties, obstacles and barriers.

It was difficult for Cherepanov, it was difficult for Mozhaisky, it was difficult for Tsiolkovsky...

We need not continue the list. An engineer must be fully prepared to fight and to stand up for his opinions, to demonstrate that his ideas are not erroneous.

Later in this book I shall be telling you about one or two people and the studies they made. I hope that getting to know the real biographies of real engineers will give you a better understanding of how important it is to have a sense of time, an ability to foresee coming events and not to yield in the fight, no matter how arduous it becomes.

Something to Think About, Problems to Solve

(Answers)

21) Drawings No. 1 and No. 3 are identical, except that drawing No. 3 is Drawing No. 1 upside down.

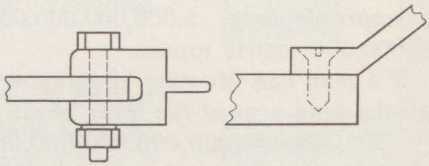
23) The squares are absolutely equal: 3 cm x 3 cm each.

24) In order to determine whether or not the coin is gold, you should first of all clean it very carefully with, for instance, tooth powder. Then calculate its volume. You already know how to do this — in exactly the same way as you measured the volume of the fork. Now you should weigh the coin, and divide the weight by the volume. If the result of this division (in gm/cm^3) is 19.3, then the coin really is gold; but if this result is only 9.65, then it is bronze.

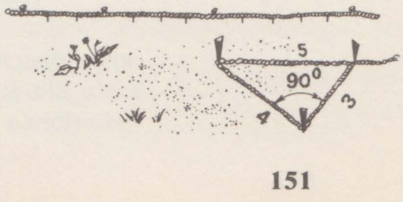
Legend, incidentally, has it that Archimedes used this very means to prove the forgery in the crown of Emperor Hieron: the gold-smith had put far more silver into his work than gold, and he was quite sure that no-one would ever expose him, as everyone would be so dazzled by the intricate and quite radiant decoration of the crown.

25) You should press button No. 4.

26) A bolt joins together components, machine parts and so on by means of a nut, whereas a screw is fixed directly into the bodies of the objects to be joined together.



27) To draw a right angle on your pitch, using no special measuring instruments, you should take the string and mark on it a distance equal to three lengths (say, three peg lengths) and then, consecutively, four such lengths, then five. Next you should join together the ends of the measured part of the string and, putting a peg at each of the three places marked, pull the points of the triangle until all three sides are stretched

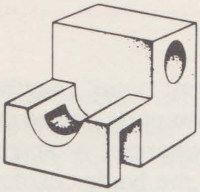


tight. The point opposite the longest side (five peg lengths) will be a right angle.

This "Egyptian triangle" satisfies the conditions of Pythagoras' theorem:

$$3^2 + 4^2 = 5^2$$

28)



30) The mass of the Earth (Archimedes was not aware of this) is equal to approximately 6,000,000,000,000, 000,000,000 metric tonnes.

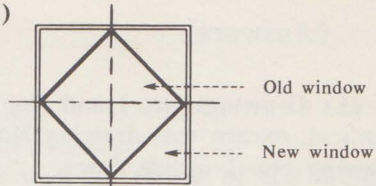
If a man can lift sixty kilogrammes, then the long arm of the lever needs to be 100,000,000,000,000,000,000,000 times longer than the short arm.

Therefore, to move the short arm one centimetre, the far end of the long arm must describe an arc some 1,000,000, 000,000,000,000 kilometres long.

If we assume that Archimedes could lift sixty kilogrammes at the rate of one metre per second (a fairly high work-rate — almost one horse power), then to lift the Earth one centimetre he would need 1,000,000,000,000,000, 000,000 seconds, or 30 billion (30, 000,000,000,000) years!

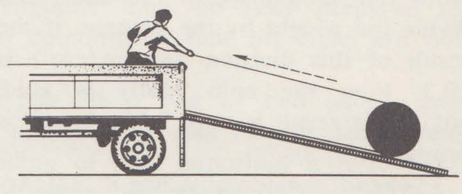
31) The first bicycle will go backwards, the second will go nowhere at all, and the third will go forwards.

32)



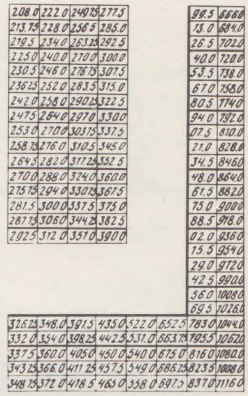
33) To roll a barrel onto the back of a lorry, you need two boards and a rope of sufficient length. Then everything is done as shown in the drawing.

Rolling a barrel using your hands can be dangerous, because if a barrel on an inclined surface gets out of control it can severely cripple anyone in its path.



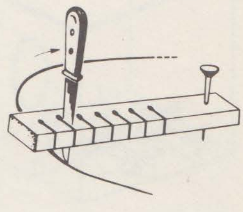
Some Useful Hints

If you often have to use calculation tables, I would strongly advise you not to use your finger to run along the horizontal rows and then down the vertical columns to find the number you are looking for. Instead, use a set square (wooden or plastic, it doesn't matter which); this will save you from making accidental errors, and will help stop you wasting many, many uncounted seconds.



If you need to make a rubber washer strictly to a given size and shape, how can you do it with very little trouble? First of all, melt some paraffin wax and pour it over a piece of plywood. Then quickly smooth a piece of rubber onto the wax.

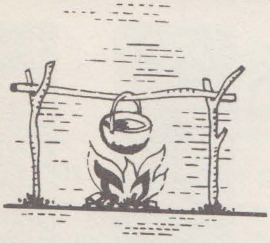
Now you can cut out your washer using a template (made by yourself, if necessary); or, if you need a circular washer, you can use a "ballerina" whose construction is shown in the drawing.



It sometimes happens that you have to measure the diameter of a piece of wire and you don't have a calliper square to hand. What can you do? Hold the wire up to a bright light source and measure the width of the shadow. This method of measurement is quite adequate for all practical purposes. Of course, in this way you can find the diameter not only of a piece of wire, but of any other round object as well.

It seems to be the fashion nowadays to light candles on festive occasions. I therefore put forward this old piece of advice: do not taper the lower end of your candles be-

fore putting them in the candlesticks. Hold them for a minute or two in hot water and you can be sure that your candles will stand up quite reliably and firmly.



Any task, even the simplest job you ever have to do, deserves to be done unhurriedly, deserves to have all the pros and cons weighed carefully before you actually *do* anything. So, is it that complicated to try hanging a pot over an open fire? There are quite a number of ways of achieving the objective: just look at the drawings and think about what dictated each approach. Then see if you can suggest other possibilities, giving explanations for any methods you suggest.

But what is the advice? — First, think about the problem; then, and only then, set about solving it.

I remember the following incident which occurred soon after I began making things in metal: I wanted to take a bronze plug out of a steel shaft. The plug wouldn't budge, as though it were welded in. I pulled at it with tongs, I tried dislodging it with a mallet, and I oiled it and oiled it, but all to no avail.

Then an experienced metal worker came up to me and said two words. The first word was "blockhead", and the second... The second word solved the problem in one, and the plug came out with no trouble at all.

So what was the second word?

Heat!

Whether you have many books of your own, or only a few, I would strongly recommend keeping a catalogue of them. Firstly write them up in a book with alphabetical divisions. This will let you know exactly what books you have. Secondly, make out a small card for each book. On the card you should write the name of the author, the title of the book, the publisher and the year of publication. Keep these cards in a special box, either in alphabetical order again, or in subject order. When one of your friends wants to borrow a book from you, he won't have to hunt through the whole library, he will just need to "take a stroll" through your catalogue. Besides, when you lend someone a book, you can make

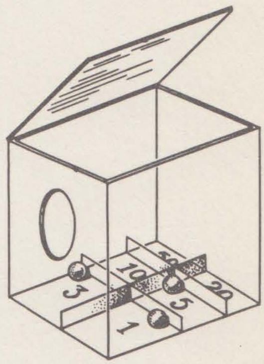
a note on the book's card, and you will know exactly when you lent the book (and to whom).

By getting used to your own card index and catalogue, you will all the more quickly learn to deal with the large catalogues and card indices in libraries; and this is very important. There are so many books in the world today — and there will be even more in the future as the number of books grows and grows — that it will be far from easy to find the one volume you are looking for if you have not trained yourself to swim in the "sea of books".

Can you think of a more pointless pastime than lotto? One person calls out numbers, and everyone else covers up the corresponding spaces on a card using counters or chips. But that is not to say that any other quiet game is totally useless. If the game is designed to develop some quality in a person's character — whether dexterity, imagination, resourcefulness, memory, concentration and the like — then I am all for it.

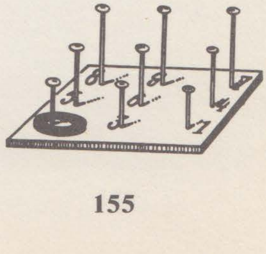
Let me suggest one or two home-made games which I think are worth playing.

It is not difficult to make a box 25cm x 25cm x 25cm. Making a hole, about 8cm in diameter, in one side of the box should cause no problems either. Then all you have to do is divide up the base on the inside of the box into six zones using small laths, and mark the zones: 50, 20, 10, 5, 3, 1.

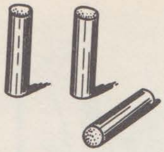


Each player has a little ball (a ping-pong ball, for instance) marked with a number or other distinguishing symbol, or a piece of coloured paper rolled up into a ball (each player having a different colour). From a distance of about half a metre or so each player in turn throws his ball into the box. In order to hit the hole you need a certain amount of dexterity and practice. And the excitement comes when you lift the lid of the box and see who has scored how many points.

The score can be kept for individuals, or it can be a team-game.

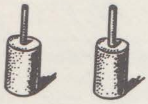


A variation of the same game is to have, instead of the box, a board with nails sticking up from it. Under each nail there is a number. For this game you need to cut out a number of rings which you will throw at the nails, trying



to collect as many points as possible. The size of the board, as well as the other "parameters", you can choose for yourself.

I warn you: this game is not as simple as it might seem at first sight, but it is an excellent way to train your dexterity and judgement of distances.



And what about miniature, table-top skittles? Take a look at the drawing, and you will easily see how to make them.

Or a variation: making the skittles out of ordinary corks.

Dates on the Calendar

1920-22

The beginning of radio broadcasting in England, the USSR, the USA and France.

1923

The first Soviet tractors are produced.

1928

The Soviet chemist, Academician Sergei Vassilievich Lebedev, makes synthetic rubber.

1929

The Soviet engineer, Boris Sergeyevich Stechkin, publishes his work: *The Theory of the Aero-jet Engine.*

1930

Mass production of hard alloys.

1930-33

Friedrich Arturovich Tsander, the Soviet scholar and inventor in the field of rocket technology, builds the first liquid-propellant rocket engines.

1931

The first television transmission is made in the Soviet Union.

Johann Winkler and Riedel make experiments with rockets.

1932

John Cockroft and Ernest Walton effect the world's first atomic reaction, using artificially accelerated protons.

1934

Frederic and Irène Joliot-Curie report to the French Academy of Sciences on their discovery of artificial radioactivity.

1936-37

The first specimens of polyethylene are made in England and the Soviet Union.

1938

The Soviet engineers, A. P. Ostrovsky and P. V. Aleksandrov build an electric drill.

1939

Otto Hahn and Fritz Strassmann report their discovery of splitting uranium atoms using slow neutrons.

1941

In the USSR a jet aeroplane is built with a liquid-propellant engine.

1942

Enrico Fermi achieves a nuclear chain reaction in a reactor at the university of Chicago.

1943

The Soviet inventors, B. R. Lazarenko and his wife, put forward the theory of electric sparks as a means of metal processing.

1945

The world's first atom bomb is exploded in the USA.

7

A Matter of Getting the Job Done. Anywhere, Any Time. On Your Own, or with Others

I met him up in the north. It was a long time ago; Aleksei Dmitrievich was about fifty in those days, maybe a little older. I remember him as a tall man, not far short of two metres; heavily built, ungainly, a bit like a bear; huge hands, dark brown, the hands of a man who had worked long and hard; and the way he talked, short phrases and long pauses, sort of dot — dash, then again, dot — dash...

I asked him:

"Have you been in these parts long?"

He answered:

"Yes... Thirty years, almost... You could say — all my life."

I asked him:

"Is life hard here?"

He answered:

"If you're not used to it, yes... It's cold... The snow... The winds... And anyway, ten months of the year it's winter; and what's left over we call summer."

Aleksei Dmitrievich was a building engineer. As soon as he had left college he set off for the Arctic and worked for a long time inside the Arctic Circle, fitting out weather stations, building aerodromes; then he was sent to Yakutia to build quays, houses and trading stations; then he was off to Chukotka, building lighthouses, laying roads, and working for a geological trust; then he flew out to...

I asked him:

"You have done a lot of building, Aleksei Dmitrievich. What do you consider has been the most important, the most interesting, the most necessary thing you have done?"

"What a question! If you've got the open sky over your head, if it's forty below with the wind blowing you off your feet, then you need to build a snow house... It's important ... and interesting, especially if you don't really know where to begin..."

I tried to approach it from a different angle:

"You obviously like the north, as you have stayed here so long?"

"Like it?! What's good about it? Onions are a luxury, rotten apples are a miracle... There's nowhere to go for a swim. It's alright reading about the north... Jack London, and all that."

"But you have been here all your life?"

"So what? Someone has to be here."

"Who?"

"People, I suppose."

It is quite impossible to describe how I wrung the information out of him! Only the youthful fervour of a green journalist gave me the endurance and patience to keep at him.

At last I managed to make my first notes — *As Told by A. D. K., Building Engineer.*

"We had to cut up a stone monolith that was blocking our path. It was easier said than done — cut it up, but how? I didn't sleep for thinking about it. That got me nowhere. In the morning I saw a book on the table — *Physics*. My neighbour's little boy was in the sixth class. The school had twenty eight pupils over the seven classes. But that's by the way. I saw the word *Physics* and remembered that water expands when it freezes. I thought about this all day. I ordered bore-holes to be drilled in the monolith. We made a hundred holes in a straight line round it, and filled them with water. In the morning the block was cut as clean as you like."

This was an incident from real life, and Aleksei Dmitrievich's conclusion was:

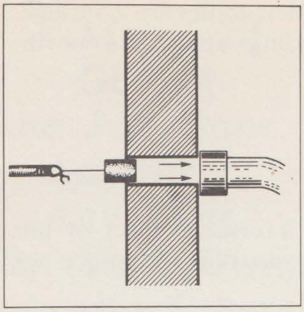
"If you know something, if you can do something — everything in the world is simple when you know how. And you have an especially good reason to be happy if you can reach this 'simplicity' using your own brains."

Later, I made another note.

"We were on a knoll, felling a wood, and using a couple of tractors to drag the timber loads down into the valley. We were going to use the timber to build warehouses. But winter set in earlier than usual. Even at the best of times there were no roads as such, and now the tractors were overstraining, going at full steam, but getting nowhere. Stop, enough is enough! What could we do? Someone said: 'Aleksei Dmitrievich, you should let head-office know — unforeseen circumstances.' Ah! 'And what are head-office supposed to do — send us some good weather in the post?' Someone else said: 'I knew it — there never was any good in these parts, there never will be, never can be.' But he was just a moaner. A third man said: 'You'll have to think of a way out, Lyosha.' So we had a think together, shared our exasperation, and thoroughly weighed up all the pros and cons.

"And in the end we came up with an answer. We made a chute in the ice from the top of the knoll down into the valley and started sending the logs down it one after the other. Very much like a conveyor belt really. An excellent idea. We had our difficulties, but we got our warehouses built."

And again Aleksei Dmitrievich generalised to draw his conclusion. It was a habit



with him — he just had to dot his "i"s and cross his "t"s. "Up here in the north," he said, "you have to use your loaf. You've just got to!"

And another note.

"We had some fellows here with heads on their shoulders. They made fairly easy meat of one problem they came up against — a whole institute could have worked on it for five years and still wouldn't have come up with the answer. We'd been harassed for years by drifting. Every day of the week in the winter the roads were swept by snow-storms. There was no time to clear them. And nothing to clear them with. No matter how many fences we put up, they got us nowhere. And then these fellows went and put the fences on top of poles: they'd come up with an idea that made the wind itself blow the roads clear. It licks them clean as a whistle. Those fellows really had heads on their shoulders!"

And this was the only praise I ever heard cross his lips.

One day we were sitting quietly drinking tea. Suddenly, Aleksei Dmitrievich said:

"You really are like pitch!"

"How's that?" I inquired.

"You stick and stick, question after question... And what can I tell you? I didn't build the Eiffel Tower. And not even a dam on the Dnieper. I don't understand a thing about atomic reactors. So what can I tell you?"

"Perhaps you can tell me what makes a real engineer?"

"An engineer? He is a man who can get a job done ... anywhere ... any time ... on his own, or with others. That's about it in a nutshell."

Next morning I quite by accident overheard Aleksei Dmitrievich shouting at one of the drivers:

"OK. Your carburettor packed up, but why did you leave your lorry? And march back all the way here, over thirty kilometres? You're an ass, not a driver... You had a spare petrol can with you, didn't you? And a feed-pipe? So why couldn't you put some fuel into the can, and put the pipe on the feed-nipple? The other end you would stick into the inlet pipe. Give the can a squeeze and — tick, you're on your way, another squeeze ... and you keep on going, no problem... Call yourself a driver! You're a cripple, not a driver."

- *Karl Friedrich Gauss, the great mathematician, set about learning Russian on his own — at the age of sixty-one.*

In August 1840, he wrote: "I now have three volumes of the works of Pushkin. I like his Boris Godunov *very much."*

At his death, his private library contained more than seventy-five books in Russian.

And Aleksei Dmitrievich went about his business, shuffling his feet in disgust. That's how I remember him: tall and ungainly, but a man who could at all times find a way out of any problem, even if the whole situation seemed to be totally hopeless.

Ten years went by.

I had recently moved into a new house and one day I called in on my neighbour. I hadn't yet had a chance to get to know him. When I went in I found him standing on a step-ladder, holding a vacuum-cleaner pipe in his hands and performing some magical rite with it up at the ceiling. When he saw my bewilderment he explained:

"I was trying to install a television cable, but the rotten thing kept catching in the hole; it wouldn't go through because it kept bending double. But I got him in the end. I fastened a thread to a cork, put the cork in the hole on the other side of the wall, and used the vacuum cleaner to suck it through to this side. Now all I have to do is to fasten the thread to the cable and pull that through."

"That's great," I said, "and so simple! Where did you learn to do things like that?"

"From Aleksei Dmitrievich," he said, and fell silent. It was like dot—dash, dot — dash — dot, as he continued: "He was an engineer... Up in the north... He could do anything... Anything..."

No, we didn't break into reminiscences; I didn't even tell him that I'd known Aleksei Dmitrievich. I just thought to myself that to be a real engineer — apart from everything else, you had to leave a new generation of real engineers behind you, to follow in your footsteps. And not just one, not just two...

It Won't Get You a Monument, but...

Zholinsky was a maintenance engineer and looked as though he had been boiled for a couple of weeks in machine oil: he was all dark brown and shiny. Only his deep blue eyes and his white, blue-tinted teeth stood out in his almost negroid skin. I first met him in the shipping-line manager's office.

The manager was asking:

"Zholinsky, Stanislav Borisovich, born 1916, working-class parents, at sea since 1930, left school at 14, completed a course at technical college in 1946?"

"Aye."

"Health?"

"OK."

The manager looked into the papers once more, and pronounced (he didn't say it, he *pronounced* it!):

"So, Stanislav Borisovich, we think it is time for you to be transferred," the manager paused, "from the *Terek* to our new dry-bulk carrier, the *Plavsk*. The *Plavsk* is Polish-built and has just been completed. How do you feel about it?"

"What do I want the transfer for?" Zholinsky asked looking at his watch.

"How do you mean, what do you want the transfer for? The *Terek*, if my memory serves me right, was built in 1919. It's a worn-out old tub, and there's far more work for you to do on it than all our other mechanics put together. Whereas the *Plavsk* is a brand new vessel, just coming into service..."

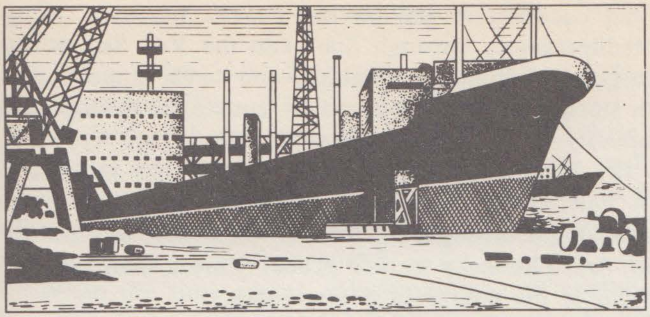
"'Just coming into service'! So what would I do on your *Plavsk*? Go round sniffing the capstans? Eh? What is there to repair when the *Plavsk* is as shiny as Poperechny's bald patch?"

Poperechny was a senior executive of the shipping-line, and Zholinsky's interlocutor winced just a little.

"I really don't understand you, Zholinsky! What are we offering you: a) the best ship we have; b) the best conditions you could wish for, and c) as few worries as it is possible to have on board ship. And you don't seem to be satisfied!"

"That's about the size of it," Zholinsky agreed. "So what?"

"Strange, very strange. Particularly as you left school at fourteen..."



"True — that was bad of me, very bad. But if you look at my experience — a), and my clean record — b)..."

"That's just it! We took all that into account: your experience, your exemplary service, and even the opinions of the people you work with. So what do you say?"

"How do you mean?"

"Will you move over to the *Plavsk?"*

"Are you trying to be funny? I've already said no. Why do you keep asking me? No! I won't transfer!"

"Perhaps if you go home and talk it over with..." here the manager looked into Zholinsky's file again, "talk it over with your wife, think about it together, and then in the morning call in and let me know?"

"Listen," said Zholinsky, "I don't need your *Plavsk,* I don't need its conditions, I don't really need anything from you. While the *Terek* can stay afloat, then my work is on the *Terek.* And that's that! And now it's time for my lunch."

Zholinsky's chair scraped the floor as he stood up and went out. The manager sighed loudly and became quite indignant.

"Really, have you seen that fellow! He is offered a brand new ship, the best possible conditions, in fact everything a mechanic could ask for, and more; and he has the nerve!.."

I, naturally, asked why he was trying so hard to pull Zholinsky over to the *Plavsk*, and he freely explained:

"There is an idea of making the *Plavsk* the flagship of the whole line. The captain will be Golovin." Here he raised his index finger. "You know, of course, he's the best captain there is. The chief engineer will most probably be Martirosyan, Ashot Yeremeyevich himself. And then, we've got to put the right team together."

I asked:

"And does Zholinsky fit the bill?"

"To tell you the truth, not quite. His education is a bit thin on the ground, his character isn't the sweetest there is, but Ashot Yeremeyevich made a personal request. If it hadn't been for that I wouldn't have tried to talk him into it."

About a month later I had occasion to sail on the *Terek*. We were going from the Black Sea to the Mediterranean, through Suez and the Red Sea to the Indian Ocean, as far as Georgetown (Pinang), Malaya, and back home again.

We were tossed around in storms, we were battered by equatorial downpours, we were choked by the humidity of tropical heatwaves. The *Terek* creaked, groaned and moaned under the hammering of the ocean waves but kept at a meticulous pace, nine and a half knots, every hour of every day. And from morning till night, and the whole night through, the mechanics, stokers and sailors toiled on, bathed in salty sweat. And Zholinsky worked probably more than anyone. Once I wrote down what he did in the course of a single day.

In the morning the stearing gear's slide valve finally gave up the ghost. Zholinsky turned on the lathe and made a new valve.

Then he cut a new thread on the pipe coupling.

After lunch he worked in the smithy making hooks for the auxiliary guy-ropes.

Before dinner he cut out new bottoms for the galley buckets.

Then he and the electrician overhauled the emergency dynamo system.

After dinner he mended the bosun's watch (a personal request).

In the middle of the night Zholinsky was roused from his sleep and called to the engine-room: the hot-water pump had sprung a leak.

This was a typical day or, to be more correct, a typical twenty-four hours — one out of the one hundred and twenty three we were afloat. During this twenty-four hours Zholinsky was a turner, metal worker, a smith, a tinsmith, an all-round electrician, a watch-repairer and a mechanic.

In Georgetown we went ashore together. We wandered around the town, enjoying the riot of tropical colours and making neither head nor tail of the noisy confusion in the eastern bazaar; but we were glad to have *terra firma* under our feet again after so long at sea. Suddenly Zholinsky wanted to rush back to the ship.

"What's up?" I asked. "We're free till twenty hundred hours!"

"So who's going to replace the ring bearings?"

I knew by this time that there was no stopping him. If he had the urge to work then not even a typhoon would stop him.

We turned back towards the docks.

We went without hurrying: it would have been difficult to hurry in the heat that seemed to be melting us. We talked about everything on earth: about the price of carpets and the taste of fresh mangos, about the second mate's intrigues and about the possibility of finishing loading the rubber a day ahead of schedule.

Then I asked him:

"Tell me, Stanislav Borisovich, do you never get tired of rushing about, from the hold up to the deck, from the deck along to the engine-room, and back down to the hold?"

He stopped, probably surprised by the question, and he answered quite seriously:

"But my job is to look after machines... How am I supposed to sit back and do nothing?"

We went back on board, and in the time left before nightfall Zholinsky managed to change the ring bearings on the petrol slide and to make himself a pair of shoes out of boxwood. He also sharpened some of his tools, mended the galley mincing machine, and spent a long time patiently putting something right in the film projector we had on board.

When the time comes, ships' maintenance engineers are given a pension and are put ashore. It is hard for them to get used to life on land, but in the end a person can get used to anything, even to the land, even to rest.

I know that no-one on earth has ever raised a monument to a maintenance engineer. But it's a pity. I am quite sure the *Terek* would have gone for scrap a long time ago if it weren't for Zholinsky. But it just keeps on ploughing the seas. And I think Zholinsky knows that as well, but he will never say anything about it to anyone.

The Last of the Mohicans

Fyodor Ivanovich Legenya was what you would call an odd sort of fellow. He was small and round, always running somewhere in excitement; he was known to everyone in the house, everyone in the neighbourhood and probably everyone in the whole town as well. Legenya could do anything: repair a motor bike or a washing machine, instal a television set, work out how a Japanese tape-recorder works, or take two electric irons that are not working and make one that does. He was flexible and reliable, but the only thing was — it was so difficult to pay him for any work he might do for you: money he wouldn't take. A "customer" would wave his hands in embarrassment, trying nonetheless to talk him round: "Come on, Fyodor Ivanovich, you spent all day Saturday on my fridge. I can't just say *thank you,* and leave it at that..." But Legenya would brush all this aside with his short, agile arms, and his face would take on a pained expression. But sometimes he would set his "client" a task to get his teeth into:

"Your money is no use to me at all, no use whatsoever. But if you want to humour me and pay off your debt, then how about finding me a sheet of bakelite plywood? OK?" Another time he would express a need, not for bakelite plywood, but for polystyrene cut-offs, or for a duralumin angle piece, or for a piece of copper tubing: but it would always be things that were hard to get hold of, rare chemical products or a special type of electric wire.

In the eyes of the world, Legenya was the manager of a pharmaceutical warehouse. At work he was inconspicuous and dependable. This was his *persona* for eight hours a day, five days a week, but the rest of his waking hours you wouldn't recognise Legenya the warehouse manager. He was an inventor, a man of unbounded fantasy, bold ideas and desperate solutions.

When I met him, he amazed me with an unexpected "welcoming speech":

"Ah, you've come to look at the madman who dedicates his leisure time to the great goddess and mistress of nations — Technology? Please do come in, although you must excuse my flat for not being too tidy." Here he stepped back into the room, presenting me with a picture of his home, crammed with all sorts of gadgets, apparatus, tools and materials. For a couple of minutes he talked in an elevated but ironical style about his passion, and he concluded: "And thus you

find me, Fyodor Ivanovich Legenya, the last of the Mohicans."

Somewhat nonplussed, I asked him:

"Excuse me, but where do the Mohicans come in?"

"Simple. James Watt, a watchmaker, invented the steam engine. Richard Arkwright, a barber, invented the spinning loom. Robert Fulton, a jeweller, invented the steam boat. Pierre Beaumarchais, a playwright, did no less for the clock industry than for the theatre. Alexander von Humboldt, an explorer, constructed a safety lamp for miners. And Samuel Morse, an artist, is famous the world over as the inventor of the telegraph. But all these are the deeds of days long passed. Today, individuals are in no position to change the world. No position at all. The age of "one-off" inventors is dead. Amen! Now it is team-work that does the inventing, building and creating of serious things: research departments, design offices, in a word, institutions. People like me are the last of the Mohicans."

Legenya smiled sadly. I felt sorry for him, and I said:

"But I have heard that you have over thirty officially recognised inventions to your name..."

He didn't let me finish:

"Yes, I have thirty-six patents altogether. Some of my things are already in production, some have yet to get off the ground. I live in hopes. I am quite confident, in fact, but that is not the point. It's not me personally that matters, it's the principle: we are dying out, but we won't give in! We have invented, we are still inventing, and we shall continue to invent!"

Legenya took a cardboard box down from the shelf and tipped a whole pile of documents onto the table. He started showing me the fruits of his work.

In an hour or so I began to notice a curiously consistent progression: when he was quite young he had invented and patented a railway without either rails or wheels. The engine and rolling stock were to fly through huge magnetic rings, touching nothing.

When he was a little older he spent a lot of time on automatic signals. First of all railway signals, then tram signals, trolley-bus signals and, finally, all-purpose signals. Patent. Success. Acclaim. Extensive use.

The Legenya of more mature years (this was during the Second World War) devoted his energies to the war effort: anti-tank mines, improvements to mine detectors, mortar design No.1, No.2 ... No.5 ... No.8, small-calibre ammo magazines for low-flying fighter aircraft, giving both accelerated and increased fire-power, sniper sights, etc...

Now as an old man, Legenya has designed improvements to various tools, geological apparatus, hiking equipment and mountain-climbing outfits.

Following his line of development, I was already making a mental note that Legenya was coming down in size, coming down to earth, as it were, but Fyodor Ivanovich forestalled me:

"You have probably noticed that with the passing of years I have stopped bothering about the transport of the future, and I am no longer so interested in

totally new forms of weapons. You might think it's just old age creeping on. But no, it's wisdom. Let the big concerns do the big work: they've got the money, and the technical basis, and they have science by the tail. It's up to us Mohicans to improve life closer to home, and not to get carried away."

Legenya then fetched a plastic pipe about a metre long and thirty centimetres in diameter. It had a small, highly streamlined capsule in the middle, with a number of finely moulded blades at its head, like a ship's propellers.

"Interesting, isn't it? If you are a hunter, angler, geologist, or if you just like spending your holidays in a tent, you can rejoice with me. What do you think it is? It's an electric power station. It weighs just seven kilogrammes and can be immersed in any brook or stream, basically in any running water. And in five minutes you will have enough power to light up a dozen tents and a full-blown radio set: in a word, it's electrification. There are two particular points about the construction: the shape of the pipe is variable so that you can funnel the flow and make it faster if necessary, and what I'm really proud of — waterproof seals on all the electric points. The dynamo can't get wet, it won't let in a single drop of water."

Looking over Legenya's experimental apparatus, I recalled the geological camp on Kamchatka in the Far East where I had once spent about a week. I recalled the cool discomfort of the dark tents, how I'd had to make my notes in the wavering light of candles (as though fate had suddenly thrown us back a hundred years or so into the past), the crackling radio and the power batteries which were so unreliable because they were continually running down.

"What else do I need to do? I need to make an ultra-sonic generator and attach it to the apparatus as a separate assembly," Legenya was saying. "What for? To protect the camp site from midges. Legenya may get the thanks for light in the camp, and then again he may not; but for keeping the place free of midges, at no extra cost, the campers should lift me up and carry me along on their shoulders! Have you ever met a rabid taiga midge?"

Next I saw a large number of plaster moulds of human hands — men's, women's and children's. The hands were in various poses — extended, slightly bent,

fully bent and, finally, fully clenched into fists.

"What are those, do you go in for sculpture as well?" I asked, looking at the strange collection.

"Sculpture? Just because they're plaster, does that automatically mean sculpture? Your thinking is too conventional, my friend." He laughed, and picked up a sketch-book. "Look. Please note that the geometry of the prehistoric spade is very little different from today's models, made by super-modern industry. Take a look at the handle, it's not a handle, it's just an ordinary, everyday stick! And what do we know about our hands? Did you know that the fingers of a good musician can play a hundred and twenty notes a minute? Have you ever realised that the most independent finger and, incidentally, the hardest worker is your thumb, and your strongest finger is your middle finger? Have you ever noticed that your index finger is the most dexterous, and that your third finger is a bit of a lazy dolt? So! I want to give hands the right instrument, not a musical instrument, but a work instrument, a tool with a new shape and new capabilities. Not just a pretty handle, but something — I don't know how to put it for the best — something so that a master craftsman can do five times more than he can at the moment. And this is not just wishful thinking. I can assure you, it is geometry plus new materials plus, of course, rejection of old habits and rusty conceptions."

"Tell me, Fyodor Ivanovich, does working on your own never get you down? I mean, if these same questions were to be dealt with in a modern laboratory, with team-work?"

Legenya didn't answer at once:

"Why should I start resenting what fate has sent my way? It's too late for that. I didn't have a proper education as a boy. Who's to blame? Me! My father tried to persuade me to learn, he kept saying: 'Study, study, study!' But I was too lazy. There's the first negative point for you. Then there were other circumstances: my family, children ... the war. I could probably have lived my life better, of course. But ... no-one can save us from the life we have lived, as they say. You see, my friend, I am sixty-three now. It's my autumn."

By the time I was leaving, it was dark in the cool of the late evening, and bright stars were shining in the deep black sky: large, southern, ageless stars.

Legenya asked:

"When are you off to Moscow?"

"Tomorrow, I think," I replied.

"Can I ask you a favour? If it's not too much trouble for you, of course. Could you find me some copper foil, about the size of a page out of a book, no more? It can be as a sheet or a roll, it doesn't matter which. I've heard you can get it at the theatrical shop on Gorky Street."

I promised.

"I would also be very grateful if you could send me a book. Norbert Wiener, on cybernetics."

I promised that as well, and we parted.

If You Work at It, then Everything's Possible

He is the grandson of a lumberjack, the son of a lumberjack, and the brother of lumberjacks and rafters; he was born in Siberia, on the Yenisei, one of the country's largest timber-floating rivers. And almost his first recollection in life was the timber, unending strings of logs, floating streets of timber, whole towns sliding downstream.

His father was a bearded, thick-set powerful man who had spent over half his life in the taiga. On his death-bed, he said: "Let Nikanor get an education, let him, at least, make it out into the world." And Nikanor's brothers, also bearded, thick-set and powerful, fulfilled their father's wish to the letter. Nikanor first went to school in Siberia, then he moved to St. Petersburg where he earned the right to call himself an engineer: but this was already after the Socialist Revolution of 1917, and the city was now called Leningrad.

I met Nikanor Stepanovich when he was turned sixty; by this time he had long been a professor and a highly acclaimed scientist. He had begun his career specialising in engines, and the subject of the thesis for his first higher degree was *Jet engines, their possible construction and their future prospects for use in air transport.* At that time, in the middle of the 1920s, it was far from clear whether it was possible to build jet engines fit for use in aeroplanes, and it was still very much in the realm of theory as to what forms these engines might take. Nikanor Stepanovich was therefore treading untrodden paths. He was young, persistent and dogged; he believed and he doubted, rejoiced and despaired; nonetheless he continued to work and hope.

But there was a man, a colleague of his, who did much to shake his beliefs. At every possible opportunity, this man tried to show Nikanor Stepanovich that the money being spent on the laboratory was being thrown to the wind. Every mistake — and there were, of course, mistakes — was blown up out of all proportion.

In the end, Nikanor Stepanovich waved good-bye to it all and went back to his home on the Yenisei.

He had not given in, he simply wanted to rest, to gather new strength. He thought to himself: "I'll wander over the taiga, blow the cobwebs away. And then, you'll see, everything will be alright."

But things turned out nothing like he had expected. He had hardly set foot in his home district when he was asked to go and see one of the local council leaders.

After a few short questions about his journey, his health and his future plans, they came to the main point:

"It's like this, Nikanor Stepanovich: our boat repairs are in a terrible state these days. We're well off target on timber production because of the state our boats are in. And we have to do something about it all, think of a way out of the problem. We have had a meeting and have decided to ask you to take over the maintenance depot."

"Excuse me, but I'm not a shipbuilder, I'm only an engineer."

"You are an intelligent and educated man, Nikanor Stepanovich, you can do a great deal. We can give you the right conditions to work in. We must save the situation."

"And if nothing comes of my work, then what?"

"We will support you. It will come out right. What do you say? Can we shake hands on it?"

And so, unexpectedly, Nikanor Stepanovich found himself in charge of the maintenance depot. He began with the list of faults. Dislodged propeller blades, broken propellers, splintered propeller shafts, dislodged propeller blades, broken propellers, broken rudder, damaged propeller, and another one, and another...

The same faults were appearing over and over again. There were not many of them. The main things to go wrong were the paddle wheels, the propellers and the rudders. The practical engineer in Nikanor Stepanovich set about the first problem: he organised the on-going repairs, and arranged to have spare propellers, wheels and rudders always available. His job was made no easier by the fact that the fleet was a pretty mixed assortment, and far from new, so that it was difficult to keep the running repairs under control; but he managed it somehow.

The scholar in Nikanor Stepanovich, however, appraised the situation somewhat differently, more broadly and more deeply. The timber fleet needed boats of an entirely different construction: no paddle wheels, no propellers, no underwater rudders. So far, he knew what was to be done away with, but he had nothing to suggest in its place. On one occasion he explained his ideas to the man who had persuaded him to take over the maintenance depot, but the only response he got was:

"So what's the problem? You come up with the design for the right sort of boat, and we'll help you with it."

"It's not so simple: come up with a design!"

He thought about it. He didn't want to think about it, but he couldn't help it. He was an engineer!

One day his eyes fell on a map of the country's waterways. Its white surface was covered in a spider's web of light blue — the rivers, streams and brooks. "Gracious! How many rivers there are in Russia!" But then he asked himself, in a more business-like fashion: "So, how many are there? And what part of them is navigable?"

The answer was stunning: three hundred thousand kilometres of waterways were not navigable, their water was flowing away uselessly, with no benefit to man.

Now he came to be haunted by the idea of a boat capable of travelling shallow waters, without worrying about sunken timber, shoals and stray logs. He knew that

such a boat was a necessity, that everyone needed it — collective farms, lumberjacks, postal workers, hunters, trading centres, geologists ... in fact anyone living or working far from major rivers.

But he still couldn't see and imagine his future machine.

In the meantime the institute, which Nikanor Stepanovich had left, was undergoing a change, and the administration asked him to return to his laboratory. He refused, and stayed on the Yenisei.

In the autumn Nikanor Stepanovich set out on a hunting trip. He was not going a long way and was travelling light: just a rucksack and a gun. Along the banks of a restless stream he ambled on a well-trodden footpath and hardly bothered to look to either side of him. Hunting was really more of an excuse than a reason. He simply wanted to be alone. To think.

And somewhere on a bend in the stream he came across another man: bearded and thick-set. Very much like his dead father, like his elder brothers. A typical man from the taiga.

The other man was leading a horse harnessed to a flat-bottomed boat.

Nikanor Stepanovich stopped: he wasn't looking at the man, but at his horse and the boat loaded high above the sides.

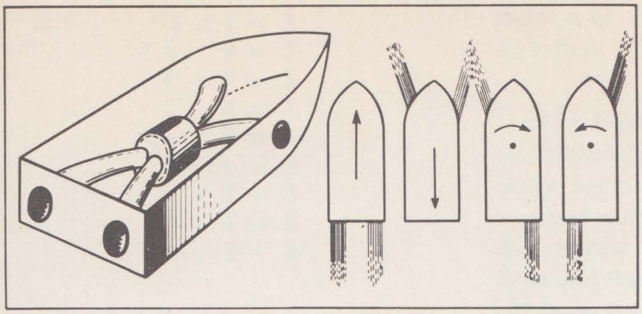
Totally unexpectedly, he saw the vision of his future versatile, ubiquitous boat. The key with which he would open up three hundred thousand kilometres of currently unnavigable rivers and streams.

The keel would have to be totally flat, not a single protruding part, no wheels, no propellers, no rudders. That was clear!

The motor would be inside the hull and attached by a drive shaft to a powerful pumping engine. The pump would draw in river water and push it out powerfully through special nozzles. Jets of water coming out the back would move the boat forward. He had found the principle of it! Now he would just have to work out the details.

It took him just one evening to draw the sketch of his "water-powered" boat. Of course it was still far from being a boat, it was only a sketch. To the uninitiated it might have seemed not only simple, but even primitive, naive. But he had to be born the grandson, the son and the brother of lumberjacks and rafters, he had to be an expert in jet engines, he had to see and experience a great deal in life — to bend and not break, to be driven mad by insults, but still retain a sober, analytical mind — he had to be an engineer by vocation, to reach this simplicity. And, what's more, he had to have a very strong will to keep at it for another ten years, improving and simplifying his construction. And to get it right in the end!

I was fortunate to be able to take a ride in this unusual boat: and I have never come across anything quite so absorbing. The craft would run nimbly over the water, stopping in an instant, and turning round on the spot, around its own centre of gravity. It could run some way up onto the bank and, once back in the water, it could make its way with ease through free-floating timber, even lifting itself over logs if necessary. Turning its stern to obstacles in its path, it could use its water jets to clear



sandy shallows, timber blockages and even to shift fairly large rocks. The small craft could, moreover, take huge barges in tow.

I have sailed on ocean-going cargo ships, been on board the atomic ice-breaker *Lenin*, felt the powerful thrust of a *Meteor* hydrofoil, and walked around a rocket-armed torpedo boat; but still, but still, my heart was always there on the stretch of the Yenisei where Nikanor Stepanovich's brain-child was tested. It would be silly, of course, to try and say that this small craft was more important than ocean liners and atomic-powered ice-breakers; let me say, rather, that a person cannot be captivated by a machine *per se*, no matter how fantastic it is. A person only yields to another person. Thus, I yielded to Nikanor Stepanovich. I yielded at the end of our long talks, when he was summing up his difficult life: I was surprised by the simplicity and, at the same time, the significance with which he said:

"In short, if you work at it, then everything's possible."

Something to Think About, Problems to Solve

(*Answers*)

34) The cranes' wedge is a most astute formation! The birds flying at the front experience considerably greater wind resistance than the ones behind: the leader cuts the air like an arrowhead. The strongest birds therefore fly at the front of the wedge and take it in turns to be the leader. And those who are weaker, younger or wounded bring up the rear, and thus neither lag behind the flock nor hold back the rest.

35) The water was boiling at four thousand metres above sea-level. It is a fact the density of air decreases with height and, at height, therefore liquids boil sooner than at sea-level.

36) Oleg should not have been so categorical when he said: "Neither of you knows anything!"

The speed of sound changes in relation to the temperature of the surrounding air. At 20°C before zero it will travel at 319 metres per second, at 0°C — 332 metres per second, and at 20°C — 343 metres per second.

37) The special feature of this multiplication is that all the digits from 1 to 9 are used in it.

38) One possible solution to the first part of the question:

5
7 3
6 4
2 9 1 8

And the second part:

2
5 4
9 8
1 6 7 3

39) Let's say your height is 160 cm. Measure your size on the photograph, and let's say this is 4 cm. Therefore the scale of reduction is:

$$\frac{160}{4} = 40 \text{ times.}$$

Now measure the height of the house, tree or cliff on the picture, and let's say, for example, that it is 18.5 cm. It is easy to calculate from this that the object in question is in fact forty times higher, i.e. $18.5 \times 40 = 7.4$ metres.

40) $3 \times 1 = 3$
$1.5 \times 2 = 3$
$0 + 3 = 3$
$7 - 4 = 3$
$^{3}/_{5} \times 5 = 3$
$18 : 6 = 3$
$^{3}/_{7} \times 7 = 3$
$-5 + 8 = 3$
$12 - 9 = 3$

41) It is possible to make a universal plug to fit all three holes. The drawings below show how. The problem, incidentally, is a practical one, not just an idle conundrum for "polishing up your brains". All draughtsmen involved in designing machine assemblies have to look for plugs like these.

42) To satisfy the conditions of the problem, you have to follow the route:

1, 3, 7, 12, 8, 4, 9, 13, 17, 21, 16, 20, 24, 29, 25, 30, 26, 31, 27, 22, 18, 14, 10, 5, 2, 6, 11, 15, 19, 23, 28, 32.

43) The writer of the diary was travelling from Astrakhan to Gorky. Rivers in the northern hemisphere and flowing north-south or south-north have steep western, and low-lying eastern, banks. As the steep bank was on the left, the diarist was travelling in a northerly direction.

44) First of all we must answer the question: why is the river flowing? Obviously, because its bed is always a slightly inclined surface. The speed of flow is determined by the friction between the flow and the channel-bed. A raft, pushed off from the bank, will gather speed because it slides down an inclined surface. The raft will gather speed until it overtakes the current. Then the water will "apply a brake" to the movement of its "passenger", just as the air slows down an object falling through it. The heavier the raft, the greater the speed with which it will float down the river. If you doubt the accuracy of this and wish to test it for yourself, please do: sitting in a freely floating boat on a river, throw a few twigs overboard. Very quickly the light twigs will be left behind the heavy boat. For the same reason oars which are lost overboard never catch up the boat from which they fell.

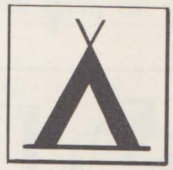
45) Since the fisherman and the man on the shore are pulling the rope, each to himself, the tension on the rope will equal the force of only one of them, and therefore there is no essential difference between this and the force exerted by the first fisherman pulling himself ashore by means of the bollard. Therefore the two fishermen will reach the shore at the same time.

Yes, at one and the same time! It is simply that in one case the fisherman's equal and opposite force is an iron post, and in the other case — a living man. That is the only difference.

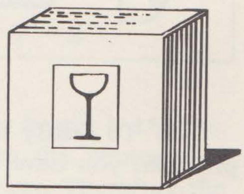
Some Useful Hints

First of all a few words about pictography. The encyclopaedic definition of this word is as follows:

"Pictography — ornamented writing, the oldest form of writing: the representation of objects, events and actions by means of conventional drawings... Pictography was widely used by the Indians of North America."



But even today pictography has not been lost without trace. International road-traffic signs, for example, have been developed on the basis of pictography. And it is totally irrelevant what a driver's native language is: if he sees a triangle with a wavy silhouette in it, then he knows that there is an uneven road surface ahead; or if the sign shows a tent, he knows to expect a camping or caravan site; etc.



And it is not only road signs which are based on pictography. If, for instance, you see a label on a cardboard box showing a goblet on a tall, thin stem, then it will be clear to you that this means "handle with care", because the box contains easily breakable objects.

In the realm of human communications there are hundreds, maybe thousands, of conventional symbols, symbols which are becoming used ever more widely.

Why not put together a "library" of modern pictography? I think you will find it both interesting and useful.

Everyday life throws a multitude of ideas your way. In the newspaper today, maybe you read about a new slabbing mill or a hydraulic giant; in a book, you came across a mention of a deflector or a semiconductor. Tomorrow you may hear something about a dyke-pool, a shutter, or a

synchro... Why not own up? You so often think along the lines: "slabbing mill, slabbing mill? That's something to do with metallurgy." Or: "hydraulic giant? Yes, I remember, it's a thing on the river."

It's not easy trying to entrust so many new ideas to memory, especially if they all come at you at once, like an avalanche.

Therefore I would very much recommend you to "collect" words, not all words, of course, but at least those in the particular field of technology which interests you: small cards in alphabetical order, each with a short explanation of the term and, wherever possible, a clear sketch or diagram which help the technical term, and the language of engineering generally, to become a habit in your brain.

I foresee the question: "And where do I get an explanation for a word I don't understand?"

Firstly, it is very often the case that the meaning of the term becomes clear in the text of the article, essay, or whatever it is you are reading (true, of course, in order not to miss the meaning, you will need to read very carefully!); secondly, in every library there are reference books, dictionaries, encyclopaedias — books written especially to explain the unfamiliar; and thirdly, you are not living at the North Pole, and all around you there are all sorts of people — so don't be shy, ask anyone who knows more than you. But also don't forget: "If you want to know about the sea, ask a sailor."

Some of my young friends complain: "I mean, I would have gone for the bread (or tidied my room, or taken the rubbish out, or taken the washing to the laundry...), I wasn't being lazy, I just forget. I mean, it went clean out of my head, and my mother made such a fuss, nearly brought the ceiling down!"

I can sympathise with my young friends. I sympathise with their mothers as well, of course. And therefore I suggest making a simple indicator board. List on it the main jobs you are given to do around the house, and opposite each job make a neat little hole.

Using this indicator board could not be more straightforward. When your mother goes out, she puts a match-

stick in the hole opposite the job she wants you to do. This means: "A job for you. Do it! Don't forget!"

When you then come home from school or your amateur engineering group, you take a look at the board and straightaway you get your instructions for the evening. After you have done whatever job you were given, you simply move the match-stick to the hole marked "Done!" So simple, and so very convenient.

If you set about doing something — whether it be making a model of some sort, solving a difficult problem, equipping your work table, etc.— try not to do anything needlessly.

Let me illustrate this piece of advice with some arithmetical examples:

Do not multiply 17 by 18 long-hand: either learn to use a slide rule (this should be an engineer's first tool), or go about it something like this: you can take 18 to be equal to $20 - 2$, OK? Multiply $17 \times (20-2)$, which should be easy enough to do in your head: $17 \times 20 = 340$, $17 \times 2 = 34$, and $340 - 34 = 306$.

If you want to know whether a given figure, say 526, will divide by three, you don't need to do the full division calculation to find out that there is remainder 1 at the end.

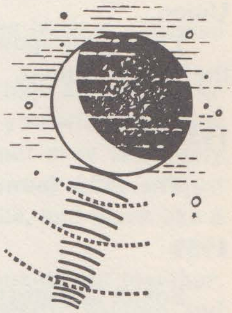
All you need to do is add up 5, 2 and 6, and with the answer 13 you can say at once that 526 does not divide by three without remainder.

And another rule for reducing calculations to a minimum. If you have to square a number ending in a 5, multiply the number in front of the 5 by the next ordinal number and write the figure 25 to the right of the result:

$$85^2 - 8 \times 9 = 72,\ 85^2 = 7225$$
$$105^2 - 10 \times 11 = 110,\ 105^2 = 11{,}025$$

The above rules for reducing calculations are not, of course, exhaustive, but I only wanted to give illustrative examples to help put over the main point — whatever you are doing, don't waste time, don't do anything needlessly.

Dates on the Calendar



1945-46

The first attempts to "read" the moon.

1946-48

The first industrial production of titanium.

1948

Norbert Wiener publishes his book on cybernetics.

1950

The Rover company build the first car with a gas-turbine engine.

1951

The first production-line helicopter, the MI-1, is built by Mikhail Leontyevich Mil, a leading Soviet aviation designer.

1953

The first all-welded bridge is built over the Dnieper River in Kiev by Academician E. O. Paton.

1954

The first atomic power station begins operation in the USSR, with an output of 5,000 kilowatt.

The Pontiac company builds an automated piston factory.

1955

The Soviet airline, Aeroflot, begins changing over to jet-powered aeroplanes.

1956

The first atomic power station begins operation in England.

1957

The first man-made satellite is launched in the Soviet Union.

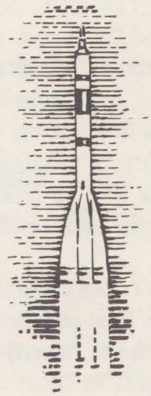
The atomic-powered ice-breaker *Lenin* is launched in the Soviet Union.

1958

The USA launches a man-made satellite.

1959

Soviet scientists take the first photographs of the far side of the moon.



1960

The USA launches an atomic-powered mixed cargo and passenger ship, the *Savannah*.

1961

Yuri Gagarin makes man's first flight into space in the satellite rocket Vostok.

At the age of eight Sasha Butlerov was sent to the private boarding school of M. Roland in Kazan. During his very first days in the school he showed an exceptional predilection for chemistry. While carrying out, at the age of eleven, secret experiments in the school's basement, he caused a great explosion and was duly punished by being confined to his room and being put on bread and water. But this was not enough for his mentors: twice a day he was brought into the dining hall and made to stand in front of his fellow pupils with the taunting legend on his back: THE GREAT CHEMIST.

His sanctimonious tutors were not to realise that they were thus the first to proclaim the talent of Alexander Mikhailovich Butlerov who was to become known the world over for his discovery of the secret of organic molecules.

At the age of twenty-six, *Butlerov defended his doctorate thesis and was soon given a professorship.*

When Engineers Get Together

The factory, of which I am about to relate, begins behind the boring, yellowed façade of a most unremarkable building.

The tall gates, the wide entrance and the notice boards are perhaps all that can be seen from the street. To understand and feel what goes on here, you will need, first and foremost, to get into the factory yard. This extensive asphalt area is densely packed with new, brand-new motor cars. There are many of them, very many, ranged in neat columns of all colours: light blue, deep red, ivory, dark blue, and black like a raven's wings.

The modern motor car is the product of thousands of components put together, tens of thousands of multifarious operations, subjected to a specific rhythm and carried out in strict sequence, in accordance with a general plan. The modern motor car is the result of the efforts of thousands of people from all sorts of professions, with all sorts of capabilities, and with a whole variety of characters and qualifications. The modern motor car, in the words of the experts, is the child of an extremely complex system, a carefully organised system, and a system divided into subsystems and even subsubsystems.

A motor car begins in the materials departments.

Huge presses turn sheet steel into the various parts of the body.

At the same time, but in a totally different part of the factory, the engine casings are cast.

And the half-axles are forged.

And strips of spring steel are put together into suspension units.

And the boxes are opened containing windows purchased from another factory.

And the wheels are mounted.

And the material for the seat covers is cut to shape.

And pipes are bent into shape for the fuel system.

And the headlights, also produced in another factory, are tested.

The components, the multitude of components, are fed to the subassembly areas in a specific, strict sequence. This is where the first units appear, the first assemblies, the "organs" of the future car. A dozen pinions — just a dozen pinions, no more; a couple of rollers — just a couple of rollers, no more. Collected in strict accordance

with the design, checked and put in place in a framework to become a completed unit, a gear-box, for instance, they are moved on, to the engine-assembly area. It is the same pattern, step by step, for the front and rear axles, and the body gradually grows, the chassis takes shape.

And all this lengthy and far from simple process is subjected to one figure, the single and perhaps the most important indicator — in this case, two minutes fifteen seconds.

Every two minutes fifteen seconds the main production line throws off a completed motor car. So what does this mean?

It means: every two minutes fifteen seconds a completed body should be mounted on a completed chassis; every two minutes fifteen seconds four wheels should be clamped on to the axles; every two minutes fifteen seconds a wind-screen should be fitted in place; every two minutes fifteen seconds the engine's power supply should be put in, the electrical system, the engine's cooling system...

Two minutes fifteen seconds is one step for the production line: it can be neither extended nor reduced; the whole life of the factory, all the efforts and thoughts of the people who work there are subjected to this one figure.

The main production line takes 350 steps a day, and the square electric "clock" on the wall keeps its own special count of time — it shows the number of cars completed in the current month.

When you walk around the factory, first and foremost you will see the labour and the craftsmanship of the fitters.

Two lads deftly picking up a wind-screen glass, dressing a rubber sealing strip around it, fitting a rubber cord into the rubber of the sealing strip, and with a sleight of hand worthy of a conjuror lifting the glass over the bonnet and setting it in place in the twinkling of an eye. (I may mention in passing that this same operation in a repair workshop takes at least two or three hours.) A fitter clamping a ready-assembled wheel onto a drum stud, using a pneumatic nut-driver to tighten all five nuts in one go. A girl straightening out the sealing rubber for the boot lid with precisely calculated hand movements — a flick of the glue brush and the rubber is fixed in place.

The engineer's work is not so noticeable, and to properly appreciate his efforts in the creation of the motor car we need to look more closely at him and delve into the myriad of problems which are constantly arising.

For everything to flow smoothly, for the main production line never to stumble, to limp or, of course, to stop, all the engineers must follow the strict formula WWH. Above all, each person in the factory should know WHAT to do, WHEN to do it, and HOW. And, of course, it must be clearly established WHO is responsible for each area of work. But don't imagine that it is so easy to set up a workable WWH system, to keep to it and to keep it under review.

The factory's main production line assembles seventeen different models simultaneously. There is the standard saloon model and the estate version, the family model and the model with hand controls, the right-hand drive... The various models follow on in a given sequence. Two estate cars, for instance, never come one after the other.

An estate car — then a standard saloon — another standard saloon — then an estate again... Why? The estate car, you see, takes a little more work than the ordinary saloon, and for the production line not to "hiccough" and for the various work areas not to be unduly rushed at any time, it is necessary to make very accurate calculations of the minimal interval between two estate cars. This is a problem for the engineers, and is not so simple as it may appear at first sight. To solve it, an engineer must be able not only to use a slide rule, but also to understand every, even the most minute, operation carried out on the production line.

Every production engineer must always remember that as soon as he says to one of the production-line workers: "This, or that, needs doing", then most probably he will hear the question: "How is it to be done?" And the answer, with reasons and explanations, must be given at once, in a precise and business-like manner.

Almost everyone who sees the work on a production line for the first time asks the question:

"Tell me, does that man fit the left-hand door every day, for example, and the man over there, does he only ever put right-hand windows in? Six or seven well-rehearsed moves, and that's all?"

No, is the answer.

The fitters are always being changed around from one operation to another. And the more operations a man is able to handle the better. Firstly, it is indispensable for production purposes, because you never know what may happen: someone falls ill and doesn't turn up for work, someone has a sudden need to go home. The whole production line cannot be stopped just for the lack of one man, the tempo cannot be allowed to fall! And secondly, the constant changing around is in the interests of each individual worker: changing from one operation to another in sequence, he — a fitter, let's say — acquires new skills and, without realising it from being an ordinary metal worker, he becomes a qualified, all-round master craftsman.

And the allocation of work, the constant movement between jobs, is also an engineer's problem, and is also far from a simple one. In solving it, an engineer is automatically not only concerned with a motor car — a dumb machine — but with people as well, creatures of reason, each of them unique in their individuality. And this

means the engineer must be objective, patient and firm, he must understand the essence of human character and differentiate between the talented and the hide-bound, he must be able to reward someone with his trust, and be able to criticise someone's work where necessary.

Let's say a man has a brilliant idea: to improve the technology of a given operation, speed up a specific job, save time. If it were a matter of making individual items, then everything would be relatively straightforward: our worker would simply make fourteen units per hour, rather than ten as planned. All praise and veneration to our enterprising worker! But on a production line it is all far more complicated. If one man squeezes his two minutes fifteen seconds down to one minute forty-five seconds. So what? The tempo of the whole production line cannot be increased just because of one successful, but isolated, improvement, no matter how brilliant the improvement may be. So is our man to do his job in one minute forty-five seconds and then have a rest for half a minute? Where is the benefit from that? And this again is a purely engineering problem: to reallocate the operations in such a way that the time saved by one man is taken out from the overall time of the production process. I have, of course, given an over-simplified example, but the basic idea holds good: the production engineer is primarily an organiser, a director and a manager of the great, very complex and often contradictory co-operation between man and machine.

What can we compare a production line to? To the flow of a non-stop conveyor belt? Enough has already been written about the conveyor belt, but I must stress that the modern production line is very unlike the literal conveyor belt. I would suggest you imagine a deep, huge river with many, many tributaries — other rivers, streams and brooks. The tributaries are of various widths and various depths; some flow faster, some flow more slowly. And on all of them there are logs, floating freely, each by itself.

And a man has to make some sort of barrier so that each log enters the main river at a particular place, at a particular time, in strict sequence... What for? To gather some of the logs together into units, to make some of these units into rafts, and to lash some of these rafts together into larger rafts of a predetermined shape and size, each larger raft having on board a hut for the rafters. This, of course, is not easy to arrange. The problem is like a huge equation, an equation with many unknowns, where the importance of each unknown is constantly changing (a blockage occurs in a side-stream ... a rogue log has blocked the flow ... a sunken log has wedged in the propeller of a tug boat ... the tug's cable snaps...), and the engineer must solve the problem taking into account the actual circumstances.

The production line is very like this river, but it is far more complicated, intricate and demanding.

Walking around the factory, I suddenly came across a group of people in excited conversation.

I had missed the beginning of the conversation, but what I did hear was: "So, you have to finish your calculations, and your pen has run out of ink. What

do you do?" And the elderly speaker pointed a fat and crooked finger at a young man standing next to him.

"I'd probably have to go and find a bottle of ink, fill my pen, and carry on with my calculations," said the young man with unconcealed irony.

"Right, you've found your bottle of ink, but you can't unscrew the cap. What do you do?" And he pointed his finger at another member of his audience.

"To open a tight bottle cap, you could try rubbing it to warm it up..."

"Enough," the old man said, interrupting him. "What do you say?" he turned to the first young man again.

"Well, if I wanted it so urgently, I would simply break off the neck of the bottle..."

"If it were up to me," put in a third lad who had so far kept quiet, "I would take out my pencil and finish my calculations with that."

"There's a man to be a chief designing engineer! Ingenious, simple, astute, and correct!"

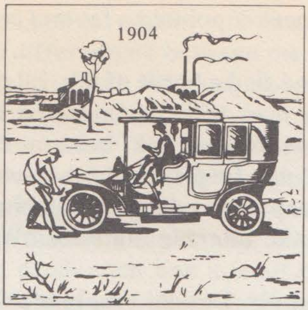
Later I got to know the old engineer better and I came to appreciate anew the conversation which had been half in jest.

The old engineer's name was Georgi Alexandrovich, and he had worked in the factory for almost forty years: he had worked on the shop-floor, had spent ten years as process engineer, tried his hand at being a designer, then chief designer, he had worked on standard models and the special versions, he had built racing cars, and besides real cars he had even built model ones.

"Above all I would like you to take note that I am happy being a production engineer," he told me. "And why? I'll tell you. Because here, like nowhere else I know, you can see the fruits of your labours. Your idea from its, as it were, ephemeral beginnings, turns into paperwork — by that I mean the drawings and diagrams — and then it finds its expression in metal. It is a really remarkable thing, you know — an idea, fashioned in metal! A production engineer, if he's not working under the lash and is an engineer by vocation, can constantly improve his work and bring it to perfection. And besides, when engineers are working together as a team, then they can do practically anything. Take us here, for example, we are always in a difficult position: we have to improve our cars and improve them again, right? But in doing this, no one is ever allowed to stop production for a single moment. Do you think it's easy? Not a bit! And yet, in the last twenty years we have increased the power of our engines fourfold, and we have changed the face of our cars beyond recognition."

Georgi Alexandrovich took a pencil and started drawing something on a piece of paper. I had already noticed that he had the habit of using his pencil to explain things while he was talking. If he wanted to say: "I was thirty-eight when I first started building racing cars", he would draw a 38 and a box round it, then with a single stroke of his pencil he would have the outline of a dynamic, low-bodied machine; and only then would he say: "I was thirty-eight..." and so on and so forth.

We talked a great deal: about the responsibilities of factory engineers, about the possibilities of educating the up and coming generation, about what attracts people to the profession and about the less glamorous side of it as well; we talked about



vocation and talent, about the price of mistakes and the bitterness of disappointment. And from our fairly lengthy conversation I would like to pick out what I think were the most interesting points.

"Above all," Georgi Alexandrovich said, "a young engineer should know what he wants..."

Volodya was one of Georgi Alexandrovich's young colleagues: at the age of thirteen he learnt to drive a car. "On the quiet", of course, not on public roads, but note: he wanted to do it, and he achieved what he wanted. Then Volodya joined an amateur technical group, began by building models and, a little later, real motor cars. After leaving school he started work on the production line in the factory. He worked everywhere on the line, from beginning to end. He was then transferred to the specialist construction section. That was when the most important part of his career began, and the hardest. He knew what he wanted: he wanted to build, test and drive racing cars. He had already learnt to drive, but building cars was not so simple. He didn't know enough about them. He started taking evening classes. But he wasn't allowed to test the cars yet: it was too early. He felt hurt by this argument, but he could do nothing about it. It took him five years to overcome this lack of faith in him, for five years he was "knocking at the door" and wouldn't go away. The result was that he is now an engineer and one of the country's champion racing drivers.

"Above all," Georgi Alexandrovich said, "a young engineer should understand what responsibility is..."

Victor, another engineer, began well. Few people begin as well as he did. His very first designs showed his independence, his originality and his unfettered imagination. His work was praised and was shown as an example to other designers of his own generation and even to some who were older and more experienced. But then came the misfortune. Although, really, there was no misfortune, as such: it was just that one of the parts he had designed was given very short shrift by the workshop's best milling-machine operator. Why? The idea was excellent, the drawings were clear and concise, but the apparently magnificent component was not feasible; it could not be realised in solid metal. These things happen, even to the most experienced engineers. But in these circumstances it is not so important that a mistake or miscalculation has

A car from the Russo-Baltic factory, 1908

been made, what is important is the stance adopted by the man concerned. He may blame it all on the machine operator, he may make up an argument about "objective grounds", he may try to justify himself by pointing out other people's mistakes, even worse ones, if he can find them.

Victor said:

"I'll have to do it all again. I shall do my best to get it done in time."

And for three days and nights he never left the drawing office. The work was done on time. The man understood, perhaps for the first time in his life, what responsibility was.

"The best engineers," Georgi Alexandrovich said, "come from craftsmen, from men on the production line, from those who have learnt about the whole machinery with their own hands."

And I couldn't tear my eyes away from Georgi Alexandrovich's large, heavy hands. I knew that there was no lathe or work-bench in the whole factory at which this very calm and very knowledgeable man could not stand and personally make the most intricate and vagarious machine part.

"If a young engineer chooses to work in the drawing office," Georgi Alexandrovich said, "simply because he is offered an extra fifteen roubles a month over what he is getting on the shop floor, then I would sign his transfer request without any regret whatsoever. But don't think that I am an idealist, that I don't care about money, that I think you can survive on enthusiasm alone. Not at all! But my experience has shown that a good engineer will get where he wants to go — it may be a little sooner, or it may be a little later, but he'll get there. And I mean a good engineer. But the person who holds the extra tenner or two above his work, above the hurly-burly of our production line, he may be a pleasant enough fellow, but he will never be what I think of as a good engineer. That, at least, is my opinion."

Georgi Alexandrovich picked up a small intricate-looking piston and carefully stroked its smooth, polished surface. I could see it was not from an ordinary motor. And while I was lost in admiration of its thorough workmanship, Georgi Alexandrovich caught my glance, and said:

"It's from an experimental motor. We're racking our brains over it, we've been

pottering around with it for so long and we just can't get it how we want it. But it's a superb piece, isn't it, truly superb?"

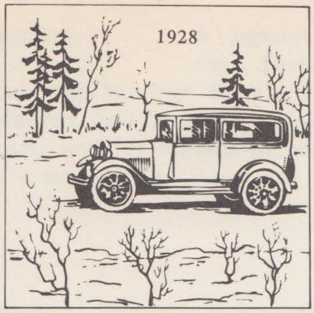
And then we got to talking again about young engineers.

"A young engineer should always know, always remember what has made Russian engineering famous. Russian engineers have always excelled with the breadth of their preparation, with their wide range of knowledge."

And totally out of the blue Georgi Alexandrovich began telling me about his father.

His father lost his parents when he was only twelve, and he began work at a very young age. It was with great difficulty that he finished the railway school, something like a modern technical/industrial college; he was a metal worker in maintenance departments, an auxiliary mechanic, and a mechanic. He got his school-leaving certificate as an extra-mural student. Then he went to the Institute of Transport Engineering. They didn't have student grants in those days, and there was no one to pay his up-keep, so he had to study and work at the same time. He took whatever work he could find: as a mechanic, a steam engine maintenance engineer, and he even tried his hand at building bridges and on other civil engineering jobs. In short, he didn't refuse any type of work. And it was amazing: by the time he finished at the Institute, he was sufficiently prepared — still only a young man — to take on the job of chief engineer in the locomotive department of the whole railway! In those days it was a pretty high post.

"Even though my father was not of noble blood," said Georgi Alexandrovich, "they gave him the post because they understood that he had the necessary experience and a good range of knowledge. And that's something that is precious today too. You can learn as much as you like from books; if you can learn anything from an ordinary shop-floor worker, don't turn your nose up at him: learn from him, it will come in useful some day; if you get the opportunity to try out something new with your own hands, don't let the opportunity go, try it! And read, read, read about everything under the sun. You may be an expert on cars, you may be up to your eyeballs in building the things, but that shouldn't mean that you can just ignore aviation, or the improvements being made in the machine-tool industry, or new electro-techni-



cal discoveries, or inventions in the field of radio, etc., etc... There is a concept of *engineer* in the sense of a job title. There is a concept of *engineer* meaning a man with a certificate to his name. And there is another, more basic, concept: I would say an engineer is a man who is able to invent things! And this is the concept I would put above all the others."

When I had left Georgi Alexandrovich and looked again at the factory yard tightly packed with new cars — light blue, deep red, ivory, dark blue, and black like a raven's wings — I thought to myself: and really, all the everyday miracles on wheels which have become so familiar to us begin far earlier than the heavy hand of the machine punch pressing a sheet of steel into the shape of the side panel for a future car body. The miracles begin when a person — still a nobody, still very young, very inexperienced — chooses his path in life. Because in the end the technical capabilities of any new machine, its future prospects, its originality and its usefulness, will all depend so much on the person who creates the machine; with what intent, with what hands and what knowledge he sits down to the enticing blue-tinted Whatman paper; with what store of experience, and with what heart too, he sets out to surpass his predecessors.

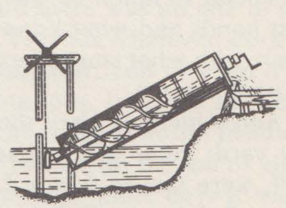
And something else I thought of while standing in the middle of the extensive factory yard: there was a time when science and technology, and probably even life itself, were moved forward by natural genii — the Edisons, Nartovs, Cherepanovs, Watts, Goodyears, Polzunovs, Yablochkovs... But now the world of machines and technology has become too complex, diverse and multi-faceted to be moved by the power of one man's brain, the talent of one individual mind. This means that even the most brilliant engineers need to start by learning to live with people, appreciate other people and understand them. But this is the subject of a different book.

A Short Glossary of Technical Terms

Alloying The addition of other materials to molten or solid metals, in order to make a compound with the required chemical composition and having the required physical properties.

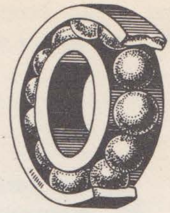
Amphibian A transport or military vehicle designed for travel on land or over water. An amphibious aeroplane (hydroplane) is most commonly a flying boat fitted with wheels; it can take off and land equally well on water and on the solid earth.

Archimedes screw A water lift. It consists of an inclined pipe with one end immersed in water; inside the pipe is a screw bulkhead. A number of such screws may be arranged in parallel.

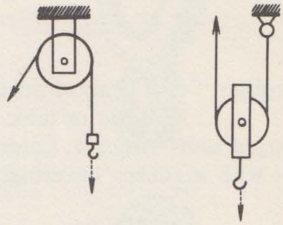


Automaton A machine which carries out, without human intervention, all the necessary motions for a particular job. The machine operator's only tasks are to set up the automaton and to supervise it. Automatons are used for a wide variety of industrial purposes: in motor vehicle production, in the textile and food industries, in the power industry, in transport and communication, etc.

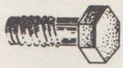
Bearing A support for shafts and rotating axes. There are bush rolling bearings and plain bearings. Bush rolling bearings include roller bearings, ball bearings, and needle bearings of various forms and for various purposes. Plain bearings consist of a sleeve or an insert and casing.



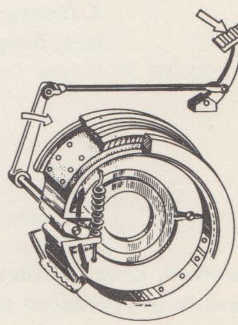
Block 1) A simple device for lifting weights; consists of a wheel, rotating on an axle, with a groove for holding a rope or chain. A block may be fixed or running. A fixed block allows the direction of the force applied to be changed, thus making its use easier. A running block gains lifting power by a reduction in the speed of lifting the weight.
2) The combination of any independent components into a larger whole, for instance, a block of cylinders.



Bolt A steel bar with a thread cut at one end and a head at the other. It is used with a nut to join individual parts of a machine, in order that these parts may be dismantled if necessary. The head of the bolt may be of various forms, the most common form being hexagonal.



Brake A mechanism for slowing down or completely stopping a moving part of a machine or the machine as a whole. The operation of a brake is based on the transformation of kinetic (movement) energy into thermal energy by means of the friction between the rotating and stationary parts of the brake mechanism.

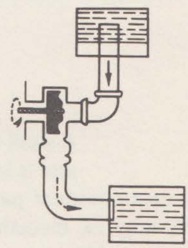


Bronzes Alloys with a copper base, in which the additive can be any element except zinc. There are tin bronzes (in which the major additive

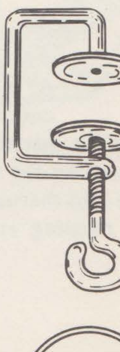
is tin) and tinless bronzes (copper-based alloys with aluminium, iron, nickel or manganese).

Cam A variety of slim crankshaft; a component of plunger pumps, steam engines, mechanical presses and a number of other machines.

Caterpillar Part of the caterpillar device of a tractor or tank, forming a continual chain of hinged units (tracks). Caterpillars can be all-metal or metal with a rubber covering.

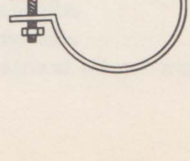


Centrifugal pump A pump with blades: the movement of the liquid is brought about by the centrifugal force arising from the rotating work wheel.



Chain A flexible part of a machine or structure, designed to transmit traction power; it consists of hinged links.

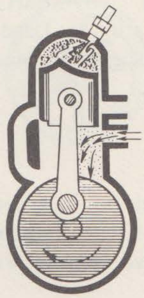
Clamp A device for holding machine parts and other objects firmly while they are being worked, or while they are being joined together. Used mainly in operations on metal and wood.



Clip A fastener, used in practically all areas of technology.

Clutch A mechanism used in motor vehicles for disengaging the engine's crankshaft from the gear box. It ensures a smooth engagement of the engine's crankshaft with the transmission. In tractors, the analogous device is called the coupling clutch, in tanks — the friction clutch.

Cog transmission A mechanism for transmitting motion by means of cogwheels and racks. The wheel moved by a motor is called the drive unit; the wheels, which pass on the motion to other components, are called the driven units.



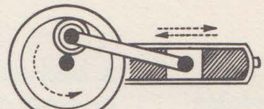
Combustion chamber The volume between an internal combustion engine's cylinder head and the lower end of its piston, when the piston is at the top dead centre.

Compression In internal combustion engines this is the relationship between the cylinder volume and the volume of the compression chamber. For carburettor engines the compression ratio is normally between 5 and 8, for gas engines — between 7 and 10, for engines with compression ignition — between 12 and 20. In turbojet engines the compression ratio is called the general pressure increase, expressed as the relationship between the maximum pressure within the engine and atmospheric pressure.

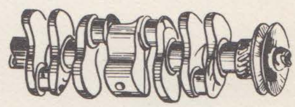
Cotter pin A wedge with only slight tapering on one side. Used in joints where there is no stress, and especially where constant dismantling or tightening is required.

Coupling A machine part for the direct transmission of rotation between shafts in alignment, or between a shaft and an adjacent idle pulley or cogwheel. Couplings vary in terms of their construction and use.

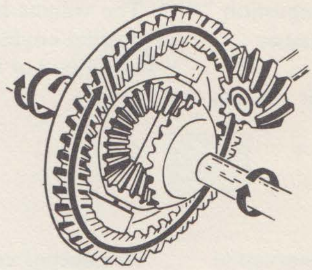
Cranking mechanism A mechanism for transforming straight-line, forward motion into rotating motion (or vice versa). Cranking mechanisms are widely used in piston pumps, compressors, engines, automatons and many other machines.



Crankshaft Part of a connecting-rod mechanism. Used in piston engines, pumps, compressors, especially those with several cylinders working in parallel.



Differential A mechanism in a motor vehicle or tractor to transmit a rotating motion to the drive wheels with a variable revolution count.



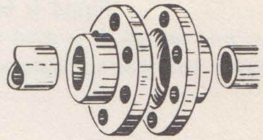
Distribution An auxiliary box on cross-country motor vehicles, allowing the distribution of power to more than one axle.

Drawing formats Standard sizes for paper used in mechanical engineering drawing. The most frequently used formats are:

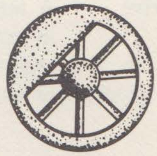
Format	Size in mm ...
0	814 × 1,152
1	576 × 814
2	407 × 576
3	288 × 407
4	203 × 288
5	144 × 203

Engine density The relationship between the dry weight of an engine and its normal power, i. e. the weight of the particular engine required to produce 1 hp. The engine density of fixed and marine engines normally ranges from 25 to 45 kg/hp, motor car engines — from 2 to 8 kg/hp, aeroplane piston engines — from 0.5 to 0.8 kg/hp, and jet engines — from 0.2 to 0.4 kg/hp.

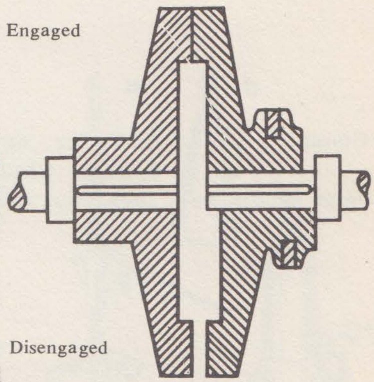
Flange A joint on pipe-lines, armatures, shafts, etc., consisting of a disc and bolt holes.



Flywheel A wheel with a massive rim, connected to a rotating shaft from an engine or to an unevenly loaded machine. A flywheel is intended to increase the uniformity of the machine's working.



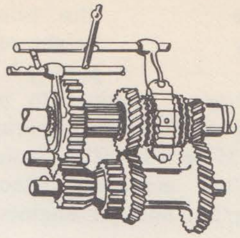
Four-stroke engine An internal combustion engine in which the work is effected in four piston movements, i. e. in two full turns of the crankshaft.



Friction transmission A mechanism for transmitting, by friction, a rotating motion between two shafts. The friction arises by pressing together two discs (friction wheels) attached to the drive shaft and the driven shaft.

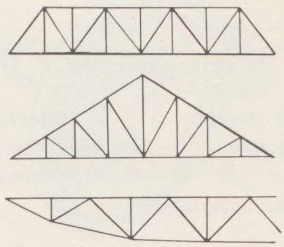
Fuel jet Part of a carburettor. Its calibrated orifice allows liquid fuel to be fed into the engine in a measured flow. On the same principle an air jet regulates the flow of air.

Gear box A mechanism which provides variability in the ratio of power transmitted from a drive unit to a driven unit, usually by means of shafts. Gear boxes are used in lathes, transport vehicles and tractors.

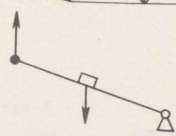


Gear pump A pump in which the movement of liquid is brought about by hollows in the pinion casings. It is used for pumping viscous liquids, in engine lubricating systems, in hydraulic drives, etc.

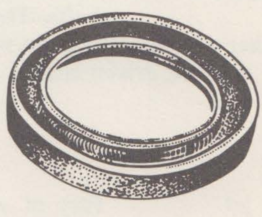
Gimbal drive A mechanism for power transmission in cars, tractors, etc., which turns shafts not lying in a straight line. A gimbal drive consists of cardan shafts and cardan joints.



Girder frame The carrying element of an engineering structure, consisting of a system of hinged bars.

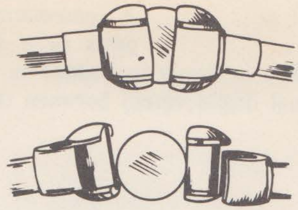


Gland A device for strengthening holes through which moveable machine parts (shafts, rods, bars, etc.) are to pass.



Gum A resinous substance which exudes from cuts in growing conifers. Turpentine and resin are produced from it.

Hinge Part of a mechanism or structure, allowing a mutual bending or rotating between the individual elements joined by it.

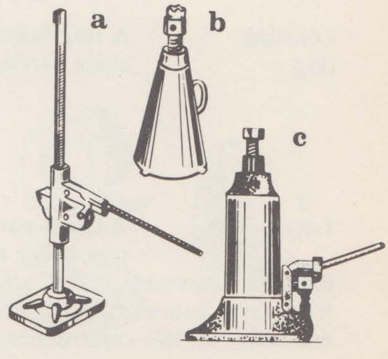


Horse power A technical unit of power, equal to 75 kg/m. sec., or 736 w.

Hydraulic machines Machines in which a liquid provides the active element. Hydraulic machines are divided into four basic types:
1) Pumps: machines giving mechanical energy to a liquid, in order to lift or transfer it, or for the creation of motion;
2) Hydraulic engines: machines acquiring mechanical energy from a liquid, such as water wheels, turbines and hydraulic giants;
3) Hydraulic transmissions: constructions transmitting or transforming mechanical power by means of a liquid, such as hydraulic drives, fluid couplings, hydraulic remote control systems, etc.;
4) Hydraulic propellers: constructions which move solid objects in liquid surroundings using the reaction with those surroundings, such as ships' wheels, propellers, water jets, etc.

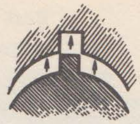
Ignition advance The angle to the top dead centre, when sparks jump between the plugs' electrodes in an internal combustion engine. In practice, ignition advance varies between 5° and 40° to the top dead centre.

Jack A mechanism for lifting weights over small distances. There are rack jacks, screw jacks and hydraulic jacks. They are widely used in construction, assembly and repair works, and also in road and railway transport.



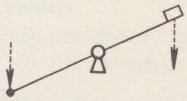
Jacks: a) rack jack; b) screw jack; c) hydraulic jack

Key A component used to fasten together parts of a mechanism or structure: the key is firmly embedded in these parts and prevents mutual displacement between them.

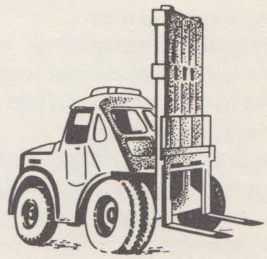


Knot A unit of speed at sea, equal to 1.852 km/hr or 0.514 m/sec.

Lever A bar rotating around a fixed support. If the point of support lies between the points at which force is applied, it is a lever of the first order. If the points at which force is applied both lie to the same side of the point of support, it is a lever of the second order. A lever is the simplest of all mechanisms.

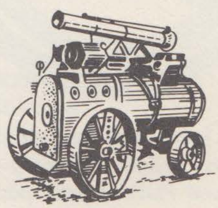


Loader A machine designed to load, unload and stack a variety of goods in piles, in warehouses, factory yards, ports, and on construction sites. The most commonly used loader is the fork-lift truck.



Locating ring A ring fastened on the shaft of a machine carriage to prevent axial travel.

Locomobile A steam-powered assembly with a gas-pipe boiler and a steam motor, the motor most commonly being located above the boiler (less frequently, below it). Locomobiles are either mobile or immobile. Mobile constructions are used mainly in agriculture and are normally around 10-25 hp. Immobile versions are most commonly connected with electricity



generators, and generally range between 300 and 350 hp (sometimes reaching 500 hp).

Machine A mechanism (or group of mechanisms) effecting certain motions for the transformation of energy or for carrying out work. The main types of machines are motor, transmission and actuating mechanisms.

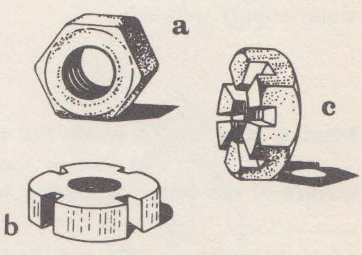
Mechanism An arrangement of interlinked moving parts (units), carrying out certain motions. The position of each unit is determined by the positions reached by all the other units in the mechanism.

Motor A machine for transforming any sort of energy into mechanical work in a rotating shaft, a pumping piston, or a jet propulsion system.

The main types of motors are: fuel motors, using fuel as their energy source; hydraulic motors, using the power of an applied liquid; electric motors, transforming electrical energy into mechanical work; and wind motors, using wind energy as their source of power.

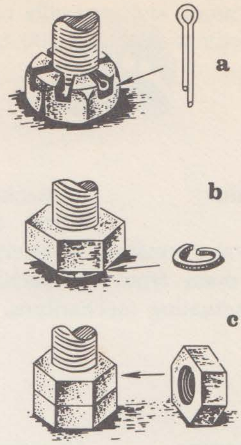
Muff A part of an easily dismantled pipe joint.

Nut A fastener, to be screwed onto the thread of a bolt or screw. A nut is used to hold bolts securely, and can be of various shapes. A lead screw nut is used to transfer linear motion to a machine bed or a lathe stand: it is often called a matrix nut.



Nuts: a) flat, hexagonal; b) figured; c) castle nut

Nut lock A device to prevent nuts from coming loose of their own accord if knocked or shaken. Nut locks may be a second nut (lock-nut), a cotter pin, a spring washer, etc.



Nut locks: a) cotter pin; b) spring washer; c) lock-nut

Octane value An indicator of the anti-knock properties in petrol. The higher the octane value, the higher the degree of compression at which the given petrol can work, while ensuring non-explosive combustion.

Perpetual motion An imaginary, unrealisable motor which, after being set in motion, will continue to work for an indefinite period without further energy being added to it. The impossibility of creating perpetual motion is predetermined by the law of the preservation of energy.[1]

Pintle A vertical axis on which, for example, the bogie of a railway carriage turns.

Pipe-line A line of tightly fitting pipes, together with the equipment for moving liquids or gasses over a given distance. Pipe-lines with many branches are often called networks, such as municipal water-supply networks.

Planing boat A small, fast boat, moving very much as though merely skimming over the surface of the water. A planing boat has a flat, V-shaped

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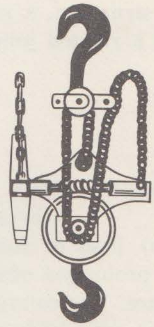
[1] As early as 1775 the French Academy of Sciences passed a resolution that no further projects of perpetual motion would be accepted for observation and testing.— *Ed.*

or concave keel, often fitted with fins (planing steps). Movement is provided by subaqueous or àerial propellers operated from a lightweight internal combustion engine.

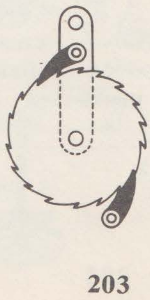
Press A machine for creating compression, used for giving a raw material the required shape, for extracting oil, juice, water, etc., for briquetting materials, for making packaging for machine parts, and so on.



Pulley A mechanism for lifting hanging weights over small distances (usually no more than 10 metres). Pulleys can be either manual or mechanical.

Pump A machine for lifting and transporting liquids, or for compressing gasses. The main types are: piston pumps, diaphragm pumps, centrifugal pumps, propeller pumps, and lobe rotary pumps. They can also be divided into high pressure pumps, well pumps, sludge pumps, etc.

Rag bolt A forged, serrated iron nail used in wooden boat building.

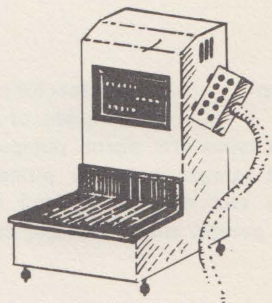


Ratchet A device allowing rotation in only one direction. It consists of a tooth-edged ratchet wheel and a dog catch. Ratchets are used in jacks, winches and many other mechanisms.

Reduction gear A mechanism to change the speed of rotation during transmission from one shaft to another. A reduction gear can be one-, two-, or multi-staged. It is used in lifting apparatus, transport, road-building machinery, and many other machines. A reduction gear in which the gear ratio can be changed is called a gear box.

Rivet A cylindrical bar with two heads, used to make a permanent join between parts of a structure. A number of rivets applied in a row are called a riveted joint.

Safety margin The ratio between the ultimate (breaking) load or force, and the actual (design) load or force. The safety margin is determined by prolonged observation of the structure or machine in use. The safety margin may vary between 1.25 and 15 (or even higher).

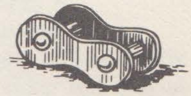


Scales

Scales An apparatus used to determine the weight of an object. Scales are of five basic types: levered, sprung, hydraulic, hydrostatic and electric. Scales conform to thirteen classes with an allowable error ranging from 0.0002% to 2%.

Screw A cylindrical bar with a thread. A lead screw is used to set various machine parts in motion. A fixing screw is used for collapsible and fixed joints.

Shackle A joint used in lifting apparatus, chain transmissions, conveyor belts, etc.



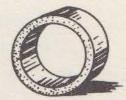
Shaft A machine part transmitting rotary force, i. e. a part that turns.

Shell A conical or cylindrical drum with open end faces. It is commonly used in the production of boilers, large pipe-lines, storage tanks, and other objects made from sheet metal.

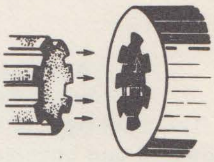
Shutters Hinged metal strips in front of the radiator in a motor vehicle's cooling system. Opening or closing the shutters will increase or decrease the flow of air onto the radiator, thus regulating the temperature of the cooling fluid.

Sketch A technical design, produced by hand, but observing all the rules of mechanical engineering drawing. A sketch should contain all the information necessary for preparing the object drawn.

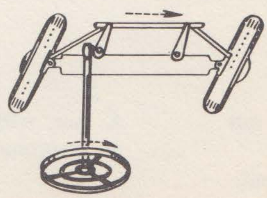
Sleeve A machine part in the form of a hollow, relatively short cylinder. A wheel sleeve (boss) is the central part of a hub, directly holding the axle. A bearing sleeve (bearing bush) is a hollow cylinder made of a special material (having a low friction coefficient) and is used in permanent bearings.



Splined joint A sealed or mobile joint, whereby longitudinal protrusions and slots are matched in the parts to be joined.

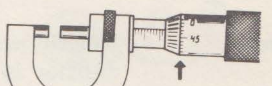


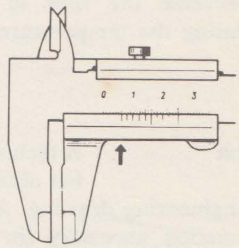
Steering The system of mechanisms and equipment used for turning the controlling wheels of a motor car or wheeled tractor. The steering consists of the steering mechanism itself, and the drive mechanism joining it to the controlling wheels.



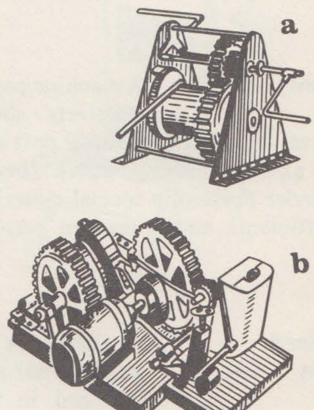
Suspension A device used in lorries, locomotives, cars, etc. It absorbs shocks arising during travel over uneven surfaces. Suspension usually consists of several steel plates of different lengths, laid one on top of the other and pulled together in the centre.

Swage 1) A blacksmith's tool.
2) A tool for shaping semi-circular rivet heads.





Transmission 1) All the parts and mechanisms for transferring rotary motion from a motor to the users of energy, i. e., to the working parts of a machine tool, or to another machine.
2) All the mechanisms transferring energy from a motor to the drive wheels of a motor car, tractor, etc.



Winches: a) manual; b) electric

Vernier An auxiliary scale on measuring instruments, used for measuring fractions of the divisions on the main scale.

Winch A lifting machine in which the lifting organ (a rope or chain) is wound on a drum. The main types of winches are: manual, electric, steam-powered and pneumatic.

Wing nut A nut with two protruding blades to facilitate tightening and loosening by hand.

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